2004
volume 14 number 1-2

# epr newsletter


The Publication of the International
EPR (ESR) Society

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The official publication of the International EPR (ESR) Society is supported by the Society, by corporate and other donors, the Zavoisky Physical-Technical Institute of the Russian Academy of Sciences, Kazan, Russian Federation, and the Swiss Federal Institute of Technology, Zurich, Switzerland.

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Please feel free to contact us with items (news, notices, technical notes, and comments) or ideas for the *EPR newsletter*.

The *EPR newsletter* is published quarterly by the International EPR (ESR) Society and is available in electronic and printed form to all members of the Society. The deadlines for submission of news for upcoming issues: Spring March, 31; Summer June, 30; Fall September, 30; Winter December, 31.

ISSN 1094-5571

**PRINTING:** LaPlume and Sons Printing, Inc.
One Farley Street, Lawrence MA 01843 USA
phone: (978) 683-1009, fax: (978) 683-4594

Dedicated to
the Nobel Laureates
in Magnetic Resonance

# epr newsletter

The Publication of the International EPR (ESR) Society

volume 14 number 1-2 2004

## Note!

In this issue you will find more than 40 links with additional material. They all start with eprnl.org, the short version of our website address www.epr-newsletter.ethz.ch we specially introduced for your convenience. The links contain speeches, music, videos, enlargements of pictures, and many complementary texts. Read them, look at them, listen to them, enjoy them! For example, while looking at the "New Horizons" photos of Richard Ernst and Kurt Wüthrich, listen to the corresponding music, or when enjoying the thangkas in the "Another Passion" column, just click on the paintings to enlarge them and then click on parts of the paintings to see more details.

Most of you will be equipped with the corresponding viewers, if not, they are available for different platforms and can be downloaded for free:

**.pdf**: *Acrobat Reader* www.adobe.com/products/acrobat/readstep2.html;

**.mp3 .mpg .rm .ram**: *Real Player* www.real.com;

**.mov**: *Quicktime* www.apple.com/quicktime/products/qt.

IES

Are you interested to become a member of the International EPR (ESR) Society? Please find the registration/information form for new/continuing members of the IES and non-credit-card payment instructions for individual members on this Web site:
www.epr-newsletter.ethz.ch/contact.html

## photo of the issue

see page 24

**Take our quiz!**
Send an e-mail message to the editor telling what Wolfgang Pauli and Niels Bohr talk about when they play tippe top. Deadline: September 30, 2004. The most interesting dialogs and the names of the authors will be published in one of the next *EPR newsletter*. The readers of the *EPR newsletter* may vote by e-mail messages to the editor to decide who is the prize winner. The prize is a nice tippe top.

# Editorial

Dear colleagues,

Imagine, nobody guessed the puzzle in the *EPR newsletter* 13/4 till May 15! However, bearing in mind that you might not have gotten the printed version early enough we took into consideration answers received by June 15 (for details, see p. 32). We also invite you to take the new quiz in this issue.

The cover of the present issue is self-explaining. Even if up to now no EPR research was awarded with a Nobel Prize, you immediately recognize the profile and name on the gold medal. This is a special issue dedicated to the Nobel Laureates in Magnetic Resonance. The idea to prepare such an issue was stimulated by the Nobel Prize in Physiology or Medicine 2003 awarded to Paul Lauterbur and Sir Peter Mansfield "for their discoveries concerning magnetic resonance imaging". We also remember our greats: Isidor Rabi, Felix Bloch, Edward Purcell, Richard Ernst and Kurt Wüthrich.

The abundance of interesting material and the desire to make it Nobel-Prize-oriented made us shift some columns you have gotten used to reading to the forthcoming issue 14/3. I am in a hurry to calm you down: one of the most exciting columns, "Another Passion", remains and demonstrates the fascination of Richard Ernst by Tibetan art. I assure you that having once looked at the multi-colored, multi-figured, multi-dimensional Tibetan thangkas, you will become addicted and charmed by their beauty. As strange as it is, they remind me of Peeter Brueghel's paintings: the same spell keeps you looking at them. The more you look, the more depths you find. Arthur Schweiger's column "For Your Perusal" activates your tactile, gustatory, visual and auditory receptors: you sit barefoot with Einstein on the beach, taste the Nobel menus, look at a video extract of "A Beautiful Mind", etc. The unique opportunity to listen to the voice of Wolfgang Pauli makes everyone who ever studied quantum mechanics shiver. Interestingly, even Pauli was told that he had to stop his talk because there was no time left!

Isidor Rabi shares with you his understanding of a scientist's responsibility. Felix Bloch tells about the debt, which we owe to youth. Edward Purcell lively recollects how nuclear magnetic resonance was discovered. You will learn what kind of new horizons may open to a Nobel Laureate on the example of Richard Ernst and Kurt Wüthrich. Paul Lauterbur and Sir Peter Mansfield kindly give an interview to the *EPR newsletter*. Hal Swartz and Al Garroway travel in time bringing the atmosphere in which the new Nobel Laureates worked in the early days of MRI. But you may not suspect that the origin of MRI dates back to the 17th century! At least, an etching of that time definitely shows a typical MRI experiment. It is thrilling to read the head-in-the-magnet anecdote (which in fact is a kind of an inverse functional MRI experiment carried out in 1949), as recollected by Edward Purcell in his letter to Herman Carr. Herman Carr's article "Synthetic Ethyl Alcohol" brings us to the origin of MRI. Several Nobel Laureates did extensive EPR in their research even if their Nobel Prizes were awarded for research in other fields. The EPR research of Aleksandr Prokhorov, Nicolaas Bloembergen, Alex Müller, Richard Ernst and Kurt Wüthrich is briefly presented. Moreover, Nicolaas Bloembergen and Alex Müller did not remain deaf to the numerous entreaties and kindly give interviews to the *EPR newsletter*.

Yes, Nobel Laureates are not celestials, they are human beings, but the grandeur of their personalities makes us admire them.

I am most grateful to all the contributors to this special issue. My special thanks go out to those who remained in the shade but whose help and support were vital for this issue to be realized: Joan Dawson, Brett Haywood, Arthur Schweiger, Ann Walker, Carlos Calle, and Moritz Kälin. Bruker BioSpin demonstrated their generosity again making possible the color spread in the center to show the Tibetan thangkas.

Not to forget, along with the previous issue 13/4 you got the 2003 directory of the IES members. Please check your listing there and update Chris Felix on it if necessary.

I do not dare take any more of your time distracting you from reading, and absorbing this Nobel issue. However, it might well be that you are lost in reading the *newsletter* and I am speaking to a wall. Welcome to the Nobel issue!

Laila Mosina

★ IES BUSINESS ★ IES BUSINESS ★ IES BUSINESS ★ IES BUSINESS ★ IES BUSINESS ★ IES BUSINESS ★

# International EPR (ESR) Society Awards 2005

## *Call for Nominations*

**Nominations are invited for:** Gold Medal, Silver Medal (Instrumentation) and Young Investigator Awards and Fellowship of the Society (see extract from by-laws below or visit website ieprs.org for full constitution and by-laws).

All nominations must be accompanied by a 100–150 word citation in support of the nomination and, in the case of the Young Investigator Award, nominees will be asked to provide copies of two recently published papers which in their judgement represent their best work. No nomination can be considered without a citation. Additional supporting material may be included.

**Nominations are to be sent to the President by email to:** tsvetkov@kinetics.nsc.ru in word or pdf format (preferred method)
**or by mail to:** Prof. Yu. D. Tsvetkov, Institute of Chemical Kinetics and Combustion, Russian Academy of Sciences, Institutskaya St. 3, Novosibirsk, 630090 Russia.

The closing date for nominations for Awards in 2005 is the 15th of November 2004.

### By-laws

A *Gold Medal* shall be awarded for distinguished contributions to EPR (ESR) Spectroscopy.

A *Silver Medal* shall be awarded for significant contributions to EPR (ESR) Spectroscopy in the area of Instrumentation.

A *Young Investigator Award* shall be made for outstanding contributions to EPR (ESR) Spectroscopy by a young scientist. Nominees should be under the age of 35 years on the 1st of July of the year of the award. The date of birth of the nominee must be included in the nomination. The nominee will ordinarily be at the post-doctoral level. Only in exceptional circumstances will either doctoral candidates or junior faculty members be considered for this Award.

A *Fellowship of the Society* may be conferred on individuals who have made influential and distinguished contributions to the practice of EPR (ESR) Spectroscopy and its welfare over a long period.

# IES General Meeting 2004

The General Meeting of the International EPR (ESR) Society took place during the 27th International EPR Symposium in Denver, August 1–5, 2004. All IES members and Symposium attendees were welcome to participate. Further details on this meeting will be given in a future issue of the *EPR newsletter*.

The EPR community has available to it a list server. The address is epr-list@xenon.che.ilstu.edu.
To subscribe to the list, send the words SUBSCRIBE epr-list to majordomo@xenon.che.ilstu.edu.
That sends a message to Reef Morse who will then manually place you on the list. This honors only legitimate requests to join the list. Reef also moderates the list which keeps it spam-free.

# Nobel Laureates in Magnetic Resonance

### Isidor I. Rabi

**The Nobel Prize in Physics 1944**
*for his resonance method for recording the magnetic properties of atomic nuclei*

### Felix Bloch and Edward M. Purcell

**The Nobel Prize in Physics 1952**
*for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith*

### Kurt Wüthrich

**The Nobel Prize in Chemistry 2002**
*for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution*

### Richard R. Ernst

**The Nobel Prize in Chemistry 1991**
*for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy*

### Paul C. Lauterbur and Sir Peter Mansfield

**The Nobel Prize in Physiology or Medicine 2003**
*for their discoveries concerning magnetic resonance imaging*

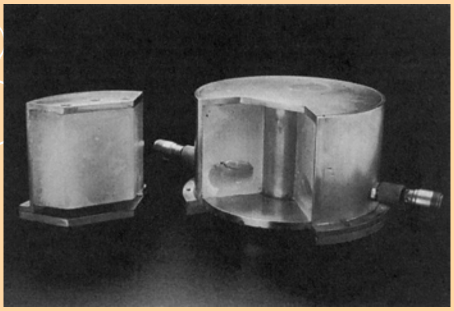
## Edward M. Purcell: on the Threshold of NMR

Edward Purcell, notes to Mattson, written in January, 1994 and reviewed by Robert Pound:

In our first full trials with everything running smoothly and the bridge balanced, we swept the magnetic current, which was controlled by the field rheostat on the generator, through a range of values chosen to bracket the current in amperes that would produce, according to our calculations, the axial magnetic field strength for resonance, $H_0$. We found no trace of a signal, only thermal noise of the expected intensity. The axial field had been on during the search, but only for short periods.

There remained the possibility that relaxation was really very slow so that thermal equilibrium had never been reached. With that in mind as we laid plans for another experiments two days later, we decided to "pre-soak" the paraffin in a strong field for at least 10 hours before searching for resonance with a suitably weak radio-frequency field. As the motor-generator could not be left unattended, this cost Purcell a wakeful night before our next experiment began on Saturday, December 15.

That afternoon the three of us gathered, still hopeful, in the shed. Maintaining a strong axial field to preserve whatever polarization might have developed overnight, we repeatedly searched as before, and found nothing. Gloomily, we reviewed our apparatus and procedure, turning up no obvious flaw. We resolved to try every extreme before switching off – including the highest current it was possible to draw from the generator. That current should have raised the axial magnetic field distinctly higher than the resonance value $H_0$. But with the generator at its limit, while our water-cooled magnet coils got hotter, there was still no noticeable



detection in the meter on the bridge – until we started decreasing the magnet current. Then the meter briefly deflected to show a clear imbalance, the signal we were looking for!

It appeared that the field had been too strong for resonance at the maximum current and had passed through $B_0$ on its way down. Actually, we had not previously tested at this high magnetic-field strength. The reason was a fault in our earlier magnet calibration; we had underestimated the saturation (decrease in permeability) of the magnet iron at the highest field strength.

Once this was understood, we found we could move up or down through a narrow band of absorption. The behavior was beautifully reproducible. It became evident that the relaxation time, which we now call $T_1$, was more like seconds than hours. That permitted a greater amplitude of the transverse RF field, improving signal-to-noise. Before we went home, further experiments had removed any doubt that we were observing nuclear magnetic resonance absorption in paraffin. Our mood was elation, slightly sobered by the thought of how close we had been to missing it.

For additional reading, see:
Purcell E.M.: Electricity and Magnetism, Berkeley Physics Course, vol. 2. McGraw-Hill Science/Engineering/Math 1984.

For Nobel Prize presentation speech, biography, Nobel lecture and banquet speech, see: eprnl.org/purcell1

For extended Biographical Memoirs, see: eprnl.org/purcell2 and eprnl.org/purcell3

# Isidor I. Rabi about a Scientist's Responsibility*

Our great need is for a better understanding on the part of the scientist that he has a real responsibility for science. This responsibility extends well beyond just doing good honest scientific work. He must try to understand the consequences of scientific discovery, and to communicate this understanding to the public. I do not mean that he must make propaganda for science but rather that he must disseminate knowledge about science, what its place in our society is now and what it is to be in the future. Whether he thinks of himself in this way or not, the scientist is the custodian of the immense inherited wealth of discovery and advance in science and technology of all the ages. He alone has the key and therefore the access to this treasure. The scientist should take the responsibility of this position in our world as seriously as the physician should take his Hippocratic oath.

* Rabi I.: Science: The Center of Culture, p. 114. New York and Cleveland: World Publishing 1970.

For additional reading, see:
Rabi I.: Science: The Center of Culture. New York and Cleveland: World Publishing 1970.
Motz L. (ed.): A Festschrift for I. I. Rabi, Transactions of the New York Academy of Sciences, New York, Series II, volume 38, 1977.

For Nobel Prize presentation speech and biography, see: eprnl.org/rabi1

For extended biographies, see: eprnl.org/rabi2 and eprnl.org/rabi3

# Felix Bloch about the Debt Which We Owe to Youth*

Our indebtedness to youth has for me two different aspects. One originates from the daily contact with my students: Their interest and enthusiasm have been a constant stimulus and a great source of inspiration and the spirit of my young collaborators has been an important factor in the success of our work.

The other aspect is of more personal nature. I am sure my fellow-scientists will agree with me if I say that whatever we were able to achieve in our later years had its origin in the experiences of our youth and in the hopes and wishes which were formed before and during our time as students. It seems that this situation is not restricted to science but is more generally human. We have just listened to the moving words of Mr. Mauriac and we have heard that it was really his life as a pupil in the province of France which, to his own surprise, has grown in his books to world-wide dimensions.

It is inevitable that many ideas of the young mind will later have to give way to the hard realities of life. But these realities will make themselves felt soon enough and while I am certainly not asking you to close your eyes to the experiences of earlier generations, I want to advise you not to conform too soon and to resist the pressure of practical necessity. Free imagination is the inestimable prerogative of youth and it must be cherished and guarded as a treasure.

For additional reading, see:
Walecka J.D.: Fundamentals of Statistical Mechanics: Manuscript and Notes of Felix Bloch. World Scientific Pub Co. 2001.
Little W.A. (ed.): Conductivity and Magnetism, The Legacy of Felix Bloch. Singapore: World Scientific 1990.

For Nobel prize presentation speech, biography, Nobel lecture and banquet speech, see: eprnl.org/bloch1

For an extended Biographical Memoir, see: eprnl.org/bloch2

* Part from Felix Bloch's address to the University Students on the Evening of December 10, 1952.

# Paul C. Lauterbur and Sir Peter Mansfield: An Interview to the *EPR newsletter*

**EPR newsletter:** *Dear Professor Lauterbur, on behalf of the readers of the EPR newsletter we heartily congratulate you to your Nobel Prize and are most appreciative of your agreement to answer our questions. MRI is a powerful method and is used worldwide. However, not too many ordinary patients know WHOM to thank for it. How do you feel about this?*

**Paul Lauterbur:** I did not do the work in order to achieve celebrity status nor do I aspire to it. In fact, I have moved on to another field of research.

*There are seven Nobel Prizes winners in nuclear magnetic resonance but there is no Nobel Prize in EPR. There is a notion that E. K. Zavoisky would have been a proper candidacy. What is your idea about any chance that any field of research studied by means of EPR could be worth a Nobel Prize?*

Zavoisky certainly made critical contributions, but his lack of a sustained follow-up effort may have limited the impact of his work, as well as the lack of a publicly visible appreciation of EPR. The field continues to develop, however, and to influence many branches of science. A coordinated campaign to select three outstanding figures in the field and to highlight the contributions to physics, physical chemistry, solid-state physics, archaeological dating, spin-trapping, electron distribution in free radicals, etc. could impress the Swedish Academy if repeated eloquently-supported nominations emphasizing the cumulative contributions of the field were submitted.

*What is your idea about the role of science for humanity?*

Science *is* one of the characteristic activities of humanity, and helps to define its nature, even among those who reject it because of fundamentalist religious beliefs.

*When you just started your road in science, who of the scientists had the strongest impact on you if any, and what was their impact?*

My interests were very broad, and no one individual stands out.

*They say that to achieve success in science you have to devote all your time and strengths to your research. However, there is also a saying that talented people are talented in many respects. How is it with you, have you any other passions, hobbies, in addition to science?*

My interests have always been various, and continue to be. They included hunting and fishing as a boy, playing tennis for many years, raising two families, history, philosophy, general fiction and science fiction, as well as a continuing fascination with the natural world.

*Is there something in your research you would have been eager to study in more detail or afresh?*

NMR microscopy was opening up new areas when I left the field, and I would have loved to explore them.

*If a fairy would be willing to fulfil three of your wishes, what would they be?*

48 hours in every day, perfect health, and an unlimited lifespan.

*What would you like to wish to the readers of the EPR newsletter?*

Joy and satisfaction in their work, and less concern over public recognition.

> For additional reading, see:
> Liang Zhi-Pei, Lauterbur P.C.: Principles of Magnetic Resonance Imaging: A Signal Processing Perspective. SPIE – The International Society for Optical Engineering 1999 (see also: *EPR newsletter* 13/1-2, p. 34)
>
> For Nobel Prize press release, presentation speech, illustrated presentation of MRI, Curriculum Vitae, Nobel lecture (video), banquet speech, interview (video), Nobel diploma, and Prize Award photo, see: eprnl.org/lauterbur1

**EPR newsletter:** *Dear Sir Peter, on behalf of the readers of the EPR newsletter we heartily congratulate you to your Nobel Prize and are most appreciative of your agreement to answer our questions. You said in the banquet speech "Many patients offer their profuse thanks that such machines now exist." Yes, MRI is a powerful method and is used worldwide. However, not too many ordinary patients know WHOM to thank for it. How do you feel about this?*

**Sir Peter Mansfield:** I feel greatly honored and delighted that the Nobel Committee has awarded Paul Lauterbur and me with the Nobel Prize in Physiology or Medicine. It does not worry me that this knowledge is known mainly to insiders. I am quietly delighted that it is known at all.

*There are seven Nobel Prizes winners in nuclear magnetic resonance but there is no Nobel Prize in EPR. There is a notion that E. K. Zavoisky would have been a proper candidacy. What is your idea about any chance that any field of research studied by means of EPR could be worth a Nobel Prize?*

I prefer not to comment on whether or not Zavoisky would have been a proper candidate for the Nobel Prize. However I am quite sure that as with any other field of scientific endeavour if it merits a Nobel Prize one hopes that it will be awarded.

*What is your idea about the role of science for humanity?*

The way I see things science and humanity are inseparable. Presumably there would be no science without humanity.

*When you just started your road in science, who of the scientists had the strongest impact on you if any, and what was their impact?*

I grew up in London during the war years and I was greatly influenced by the German science which rained down on us during the V1 and V2 bombardments of London. At the end of the war I was 11 years old and had the idea that I wanted to look more deeply into rocket propulsion. Eventually at the age of 17 I managed to obtain a position in the Rocket Propulsion Department of the then Ministry of Supply at RPD, Westcott, near Aylsbury in Buckinghamshire. I studied part time for University entrance and after serving in the British army for 2 years I joined the University of London to study for an Honours Degree in Physics. Following this 3 year course I was invited to stay on to study for a PhD working with Professor J. G. Powles on nuclear magnetic resonance. Following this I went to work with Professor Charlie Slichter at the University of Illinois at Urbana, Illinois. By this time my interests had moved away from rocketry to nuclear magnetic resonance.

***In your personal homepage it is said that you have interests outside Physics: languages, flying (you hold a private pilot's license for both airplanes and helicopters) and reading. Could you please tell us in more detail about your other passions?***

I took up flying in the late 80's. I completed a course in fixed wing flying which led to the PPL for light aircraft. Having completed this in just over 40 hours of flying I went on to do a similar course in helicopters. This took somewhat longer to achieve and I think I spent 50 or 60 hours in total before I got the PPLH. I studied French and German at school and became reasonably proficient in French especially after I spent approximately 1 month with a family in France at the age of 15. Later in my career I spent 1 year sabbatical leave from the University of Nottingham to work with Professor Karl Hausser at the Max Planck Institute for Medical Research in Heidelberg. The experience in Germany was invaluable and allowed me to revive my interest in the German language.

***Is there something in your research you would have been eager to study in more detail or afresh?***

I am still reasonably active in research and my current interest is the reduction of acoustic noise which is produced inside magnetic resonance scanners.

***If a fairy would be willing to fulfil three of your wishes, what would they be?***

My first wish would be for good and lasting health. My second wish would be for continued happiness and my third wish would be to have a further three wishes.

***What would you like to wish to the readers of the EPR newsletter?***

As well as health and happiness I would like to wish the readers of the *EPR newsletter* strength and perseverance in their research endeavors.

For additional reading, see:
Mansfield P., Morris P.G.: NMR Imaging in Biomedicine. Advances in Magnetic Resonance (Waugh J.S., ed.). Academic Press 1982.

For Nobel Prize press release, presentation speech, illustrated presentation of MRI, Curriculum Vitae, Nobel lecture (video), banquet speech, interview (video), Nobel diploma, and Prize Award photo, see: eprnl.org/mansfield1

# Some of my interactions with Paul C. Lauterbur

## Hal Swartz

Dartmouth Medical School
Hanover, NH 03755-3863, USA

I first got to know Paul Lauterbur in 1974, when I was organizing a new Gordon Conference on Magnetic Resonance in Biology and Medicine. This was a special conference that was supposed to go for only one year, but in fact has continued every other year since then. The aim of the conference was to try to sort out areas of controversy in the use of magnetic resonance in the study of cancer. On the EPR side we were looking at the various theories and claims relating free radicals to cancer. On the NMR side there were the controversies regarding whether NMR relaxation times gave a specific diagnostic indication of the presence of cancer. The idea behind organizing the conference was simple and, in retrospect, quite naïve. With help of funding both from the Gordon Conferences and a grant from NIH, the aim was to bring together principal individuals on both sides of both controversies and, in the course of scientific presentations and discussions in the intimate and intense atmosphere of a Gordon Conference, to sort out the bases for the discrepancies. This, hopefully, would lead to a consensus if not on the facts, at least on the experiments that needed to be done to resolve the controversies. In addition to the speakers who were directly involved in the controversies, we also looked at other biological applications of magnetic resonance, and it was in this context especially that Paul was an invited speaker. He had recently published on a new and strange approach, called zeugmatography. This is from the Greek word zeugma – bringing together or yoking together. The idea, which I thought clearly was not going to amount to very much except perhaps being of some instrumental and theoretical interest, was to form an image based on NMR spectra whose position was defined by using a series of magnetic field gradients, which shifted the position of the resonance in a way that could be related to their spatial position. This simple but elegant idea made it feasible to obtain spatial resolution of macroscopic objects by back projection of the features obtained with the various gradients, obtaining a picture of the material being studied. He showed some very fuzzy but fascinating pictures of things such as fruits, some of which had pits. It also turned out that he was a very nice and gracious person. We had a number of very pleasant conversations. His work was sufficiently impressive that, at the Gordon Conference, it was decided that he would organize the next meeting to occur in two years. As it turned out, organization was not Paul's strong suit so the next meeting was organized by a group, including Paul. At that time, 1976, the term magnetic resonance imaging (MRI) supplanted zeugmatography. It was also attracting increasing attention, and therefore rapidly supplanted EPR as the main topic of the Gordon Conference. Over the next several years the concept and the possibilities of MRI grew very rapidly, with Paul usually in the vanguard. In addition to his approaches in imaging, he also had a leading role in the recognition of the potential value of using paramagnetic materials as contrast agents for NMR.

The next period of intensive interactions with Paul occurred when he and several other leaders in the field decided to establish a scientific society for magnetic resonance in medicine. Although there is a general consensus that the title of the field "magnetic resonance in medicine" was chosen to avoid the word nuclear, Paul has said to me on more than one occasion, that his motivation for choosing the name was to make sure that electron paramagnetic resonance was included. Indeed, when the society was formed, there were representatives from both NMR and EPR. There was a proportional representation in terms of the status of the two fields as potential medical applications; that is, there were 17 people from NMR and one from EPR. Fortunately, however, I was the person from EPR and therefore had an opportunity to get to know Paul and his family very well as we worked together in the Society for more than ten years. For several of these years I also was secretary of the Society as well as a member of the board of trustees and therefore had an opportunity to work closely with many of the leaders in the field, including Paul's co-recipient of the Nobel Prize, Peter Mansfield. During the years that Peter was the president, I was the secretary of the society, so I had a lot of interactions with Paul's co-recipient and also, expanded on this, Peter was a candidate for a position at the University of Illinois.

It was in the course of that search at the University of Illinois that I began my closest association with Paul. I was strongly involved in the search for someone to lead a program in MRI at the College of Medicine at Urbana Champaign, in the early 1980's. We had decided that it would be desirable to get into the burgeoning field of MRI in a big way, by attracting a leader in the field to the new program. The next couple of years we negotiated with both Paul and Peter, both of whom made several visits. Eventually, however, it was Paul and his wife Joan Dawson who selected the association with Illinois. While their daughter Elisa was still in utero, Paul and Joan were visiting to finalize the arrangements to come to the University of Illinois, and we began our tradition of having Thanksgiving dinner together. We continued this tradition till 1992, when I left Illinois to come to my present position at Dartmouth. When I was in Illinois we had many opportunities to interact. I was a senior administrator of the medical school, and Paul was our star faculty member. Joan was also a leading member of the medical school, and she and I had appointments in the same department, physiology and biophysics. Joan's laboratory space, with Paul's original MRI imaging instrument, was next door to our EPR center, and in fact, we moved out of that room to make room for them to be there. We were glad to do this, because of the overlap in interests and the importance of their research. While at Illinois, we had some limited but significant scientific interactions in the areas of imaging and contrast agents, and I am very proud that I have a paper on which we are co-authors (R. K. Woods, G. Bacic, P. C. Lauterbur, and H. M. Swartz): "Three Dimensional Electron Spin Resonance Imaging" in J. Magn. Reson. 84, 247–254 (1989). We also had frequent interactions through my responsibilities as the director of the MD/PhD program. Paul had several of our students and always was a most effective and considerate mentor for them.

After we moved to Dartmouth, our interactions became less frequent but we have stayed in touch. When I was preparing a presentation on the early days of magnetic resonance in medicine and needed some materials from early meetings, I called Paul and he promptly shipped me his whole file, asking only that I eventually return it (I did!). This was absolutely typical of Paul – in spite of the many awards and accomplishments that Paul has received, there was no barrier to meeting him and talking to him about any scientific or organizational aspect.

On a recent birding trip to Panama in December, where our group consisted of two other couples plus the leader, one of the other couples was from Sweden. It turned out that he also had a PhD in Biochemistry and we started to talk about science. In the course of talking about our scientific interests it turned out that he knew quite a bit about magnetic resonance. He had done his first thesis research with Anders Ehrenberg, including some EPR. But his most recent familiarity with magnetic resonance had come during the selection process and then the hosting that were part of his duties as the secretary for the committee for the Nobel Prize in Medicine. He had scheduled the trip to Panama as a break after a hectic two weeks in which he helped to escort the recent Nobel Prize winners in Medicine to the various official and unofficial functions. He agreed, with great enthusiasm, that Paul was not only a great scientist who richly deserved the prize, but that he and Joan were also great human beings. An evaluation that I heartily share!

# Awards

## The Zavoisky Award 2004

**Kev M. Salikhov**
Kazan Physical-Technical Institute
Russian Academy of Sciences
Kazan, Russian Federation
and
**Dietmar Stehlik**
Freie Universität Berlin, Berlin
Germany
*for their innovatory work in the theory and application of electron paramagnetic resonance to problems of chemistry and biochemistry*

## The JEOL Young Investigator Prize 2004

**Dariush Hinderberger**
Max-Planck-Institut Mainz
Mainz, Germany

Detailed information on these awards will be given in a future issue of the *EPR newsletter*

# Origins of MRI at Nottingham University – A Personal View


## Allen N. Garroway

US Naval Research Laboratory
Washington DC 20375, USA


It was a great personal pleasure to learn that the 2003 Nobel Prize in Physiology or Medicine was bestowed on Sir Peter Mansfield and Professor Paul Lauterbur. All of us who have worked in MRI feel a great pride in the benefits that have flowed from those efforts, from the first rudimentary images of test tubes of water, to the latest, most refined developments in functional MRI. We all are enhanced by this Award.

I had the pleasure to attend the Nobel Prize Ceremony in Stockholm in 2003 and to listen to Peter Mansfield when he presented his Nobel Prize Lecture on the 8th of December 2003, outlining some of the history of MRI at Nottingham. I have some personal knowledge of those early days of MRI at Nottingham.*

In February 1972 I joined Dr. Peter Mansfield's group at Nottingham University as a postdoctoral fellow. I had just completed my PhD with Professor Robert Cotts of Cornell University on diffusion in metal ammonia solutions. I was interested in the multiple-pulse line-narrowing techniques that Mansfield was developing to suppress the dipolar coupling in strongly coupled homonuclear systems so that the more subtle effects of the chemical shift could be recovered in solids. In the group at that time were research students, Denis Stalker and Peter Grannell (later a postdoc).

One day in the early summer of 1972 as Grannell and I were having morning coffee in the Physics tearoom, Peter Mansfield pulled up a chair and said, in essence: "I've had this really crazy idea. It seems that one could measure atomic separations in crystalline materials by imposing a magnetic field gradient and observing the resulting NMR diffraction pattern". Grannell rolled his eyes. From my experience in pulsed gradient diffusion measurements, I volunteered that the required magnetic gradients would need to be immense and, further, that the alignment and the perfection of the crystal would need to be of the order of crystal lattice dimensions. I may have also suggested that the basic idea, of using a gradient to obtain spatial information, had already been demonstrated. We three batted ideas around for a while. When I returned at tea time, Mansfield and Grannell were still in extended conversation.

Mansfield and Grannell vigorously pursued this diffraction idea. However, Grannell's 'rare spin' spectrometer was not appropriate to demonstrate NMR diffraction. So Stalker, Grannell and I performed a rudimentary 'imaging' experiment illustrating the aspects of diffraction. We felt that imaging a liquid would be too trivial, so instead we imaged a solid, camphor, a plastic crystal in which intermolecular proton dipolar couplings are attenuated by rapid molecular reorientation. We employed one of Mansfield's line-narrowing sequences, now called MREV-8, to reduce dipolar couplings, and obtained the one-dimensional interferograms (pseudo-fids) and respective Fourier transforms of a series of slabs of camphor, to a resolution better than 1 mm.


That first Nottingham imaging work [1] was presented in a talk by Peter Mansfield at the First Specialized Ampere Colloquium in Krakow, Poland, in August 1973. Sitting in the back row with Peter Grannell during that talk, the pieces fell into place for me, and in that epiphany I saw that magnetic resonance imaging was indeed going to impact medical science. After Mansfield's Ampere talk, a questioner from the audience, Professor John S. Waugh of MIT, asked if this approach was related to Professor Paul C. Lauterbur's (SUNY at Stony Brook) 'zeugmatography' just reported in *Nature* [2]. At the time, none of us had seen that work. I seem to remember that Waugh in his remarks alluded to a 'zeitgeist': when ideas are 'ready', they seem to spring spontaneously and independently from many sources.

On return to Nottingham after the Krakow meeting, Grannell and Mansfield continued their imaging work [3] and while Stalker and I pursued understanding the limitations on the spectral resolution in the line-narrowing experiments. In February 1974 my friend, Dr. Waldo S. Hinshaw, at the time a postdoc with Professor E. Raymond Andrew, returned from an ISMAR meeting in Bombay: he had heard Lauterbur's presentation there, and was fired up about the prospects for NMR imaging.

I thought further about the possibilities of NMR imaging and realized it could be used to image flow fields in liquids, both the spatial variation of the velocity field and also the velocity distribution function. In a demonstration experiment, I destroyed magnetization in a restricted region with a $\pi/2$ pulse and then waited a further time before 'imaging' with a magnetic field gradient perpendicular to the tube axis. This way, one sees signal only from the fresh spins that move into that region; the number of fresh spins and hence their signal is proportional to the local velocity in the laminar flow field [4]. In that flow experiment, the region was restricted quite crudely: I wrapped copper foil around the tube to (somewhat) shield those regions from the RF field, and left unwrapped the

* Adapted in part from Garroway A.N.: Origins of MRI: a Personal View. Encyclopedia of NMR (Grant D.M., Harris R.K., eds.), vol. 1, p. 334. John Wiley and Sons 1996.

region of the tube to be interrogated. Were there any better ways to excite spins in one region of space and leave others unperturbed? I had just read of the method of 'selective irradiation' by Tomlinson and Hill [5] that used weak pulses to excite only a part of an inhomogeneously broadened line. I realized that such a method could then be used in NMR imaging to excite just a slice of the overall sample, inhomogeneously broadened by the applied magnetic field gradient.

I immediately implemented such a selective irradiation approach on our line-narrowing spectrometer, a homebuilt system operating at a proton frequency of 9 MHz (!) controlled by a Honeywell 316 computer with 4K [*sic*] of memory. (Within this 4K of memory, I could generate very elaborate multiple-pulse sequences, acquire up to 1K of data, and perform a 1K fast Fourier transform.) My naive notion was to define a region by applying a pulse sequence that was essentially the Fourier transform of the desired region. This is not a bad approximation provided the effective nutation angles are less than $\pi/2$. I wrote a machine language program to Fourier transform an arbitrary spatial profile, and then to automatically generate the machine language code that provided the correct pulses and delays to the transmitter. I was extremely pleased with those first results [6], showing a narrow selectively irradiated slice excited from the semicircular profile of a test tube of water, the same geometry I had used at Cornell to measure magnetic field gradients for the diffusion measurements.

Just as I was doing these selective irradiation experiments, Mansfield and Grannell had some imaging experiments they wanted to try out on the 9 MHz spectrometer. Indeed they had also realized that spatial restriction was quite useful if one wished to image a fully three-dimensional object. Their approach was to use saturation methods, that is, a train of weak pulses, to destroy magnetization in unwanted regimes, in contrast to the selective excitation.

Grannell, Mansfield and I recognized we were all taking the same basic approach to slice up an object for imaging. That approach [6] we pioneered, selective RF irradiation to excite specific regions of a sample, finds substantial application in modern MRI.

Professor Mansfield continued to make seminal contributions to MRI, through the invention of echo planar imaging (EPI), a method that allows essentially simultaneous scanning of a plane, and echo volume imaging (EVI), an analogous method for volumes. It is only recently that these approaches have been implemented commercially, owing to the severe technical demands. But, such methods may be necessary to avoid blurring by aperiodic motional artifacts, such as in heart imaging.

Mansfield had created a fine environment in the laboratory. Our small group worked well together, and Dr. Mansfield was always encouraging us and providing serious physical and mathematical insights. Our equipment, primarily homebuilt, was quite modest even by 1970s standards, but yet we were able to implement some very sophisticated experiments. Perhaps that is one advantage of not being tied to commercial equipment, or to research grants with a very focus.

It is quite remarkable that such a far-reaching medical technology has flowed from those early works at Nottingham, at Stony Brook, and the many other laboratories worldwide. More remarkable is that Professor Mansfield has maintained a staying power in the field over the past 30 years and continues to make contributions to MRI. It takes time, effort and commitment to make things happen.

In the words of a colleague, 'the Nobel Committee got it right' and the recognition for the inception of MRI has been appropriately, albeit tardily, recognized in 2003.

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# Magnetic Resonance Imaging in Retrospect

## Inverse Functional MRI

Functional MRI (or fMRI) is extensively used nowadays to study which parts of the brain are activated by different types of physical sensations or activities, such as sound or the movement of a subject's fingers. The method is based on the fact that when nerve cells send impulses, they metabolize oxygen from the surrounding blood. Within a few seconds after a burst of neural activity, a hemodynamic response is observed, so that the corresponding region of the brain is infused with oxygen-rich blood. Oxygenated hemoglobin is diamagnetic, while deoxygenated blood is paramagnetic; MRI is able to detect the small difference between the two.

Already in 1949, Edward Purcell was wondering if he could feel any sensation when he holds his head in a magnetic field, irradiates the head with radio frequency, and sweeps the field through the proton resonance. This is a kind of an inverse fMRI experiment, because it is not the NMR signal observed in a particular region of the brain after some activity of the subject which is of interest, but it is rather the resonant spin that should cause a psychological or physiological sensation.

To come directly to the point: the experiment carried out by Edward Purcell and his colleagues failed. It might, however, be of interest to learn about this experiment, as it has been described in a letter of Edward Purcell to Herman Carr on November 28, 1983. We present here extracts of his description:

*…The experiment was done by Norman Ramsey and me around 1949… The magnet and its power supply had been finished: the tank wasn't quite ready to be put into the magnet. There was plenty of room in the gap, not merely for heads but for whole bodies, with field strength up to 16'000 G. We were not trying to measure the proton resonance in the head to see if thinking modifies it…* [this would be related to the normal fMRI]

*…The idea for the experiment had come to us as we were discussing an article that has recently appeared concerning the navigation of homing pigeons… That led indirectly to a dif-*

*ferent question. Was it conceivable that flopping protons somewhere in one's head would evoke a sensation? That we could try. And for that a strong field seemed more interesting than a weak field. We were not expecting, in any case, to discover a physiological rf amplifier…*

*…Our apparatus consisted only of a pair of coils …, an rf signal generator (probably our old workhorse, the General Radio 805C) and a sufficiently long cable. We went over to the cyclotron lab one night and got the magnet powered. One of us – I have forgotten who went first – crawled into the magnet gap with the coils on either side of his head. The other cranked the signal generator through a frequency range appropriate for the field strength. No sensation. We traded places: no sensation. I presume we set the field at 12 kG or lower, for the 805C did not go above 50 MHz. But I think we did run the magnet up to 16 kG just to see if we didn't notice any other effects. I remember that rocking my head in the strong field caused an "electrolytic taste" in my mouth – which would not have surprised Faraday! My mouth then, as now, was rather full of stainless steel bridgework. I did not notice the flashing lights that people have occasionally reported…*

*…It was the kind of experiment in which only a definitely positive finding could be called a result… Had we carried out, or even attempted, an actual NMR observation of a proton resonance in the head, you would certainly have heard about that. I have occasionally described the experiment orally, and so has Norman. There is no description, as far as I know, in print. But anecdotes are not necessarily uncheckable…*

# Synthetic Ethyl Alcohol


## Herman Y. Carr

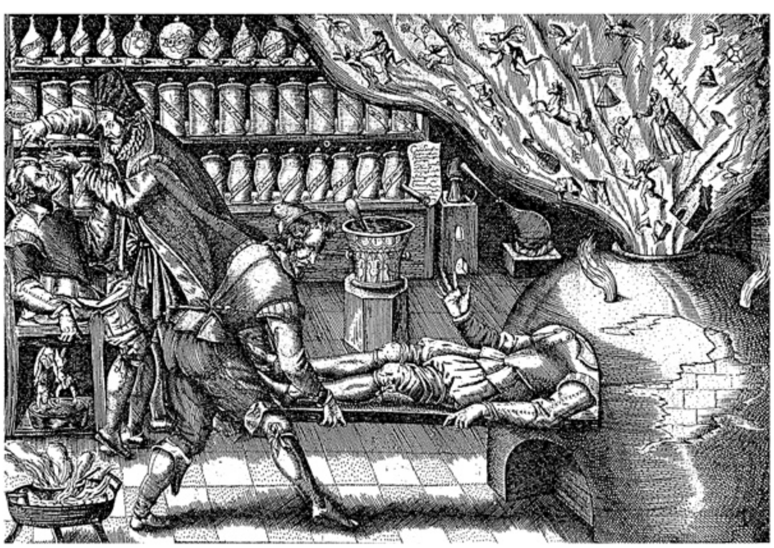
Professor Emeritus, Rutgers University, Piscataway, New Jersey, USA


The 2003 Nobel announcement honored Paul Lauterbur and Peter Mansfield for their extensions of MRI into medical applications – Lauterbur to more than one dimension and Mansfield to faster speeds. In most medical discussions of MRI, little attention is given to the earlier use of MRI in physics.

Most of the results in my 1952 Harvard PhD thesis [1] involved only internally homogeneous samples, but one MRI result distinctly involved the use of an internally inhomogeneous sample. Only a portion of the work [1] could be included in the 1954 Carr-Purcell paper [2]. Included, along with various pulse methods for measuring $T_2$ and $T_1$ NMR relaxation times, were the first use of 180° pulses, the Carr-Purcell pulse train, and discussion of the new relationship between the Free Induction Decay (FID) and its Fourier Transform (FT) in the new pulsed NMR technique which soon replaced much of the earlier but slower steady-state field-swept technique. (The later important contribution of Richard Garwin to the development of the Fast Fourier Transform (FFT) is described in my 1996 article in the Encyclopedia of NMR [3].) Also included in ref. 2 is a description of ref. 1 which first intentionally involved a linear field gradient to provide correlation between the NMR proton frequency and the spatial coordinates at the proton location. This was introduced in connection with diffusion and flow (convection) studies. It also became one of the basic parts of MRI as reported elsewhere in ref. 1. But like a number of other thesis results – electric shims, spinning of samples, gradient echoes, etc. – this was not included in ref. 2.

The diffusion and flow effects on the NMR signal had their origin in the motion of the protons through a linear field gradient (random walk for diffusion and steady motion for flow). The origin of the MRI effect was the inhomogeneous internal structure of the motionless proton sample in the linear field gradient. The first intentional use of such gradients to attain spatial correlation for diffusion measurements was in ref. 1, and this may also apply for flow and MRI studies.

The motivation for the MRI work in ref. 1 was to help faculty and graduate students visiting my laboratory understand the rather complicated NMR fine structure in ethyl alcohol ($CH_3CH_2COOH$) recently observed at Stanford University. To accomplish this I constructed a special object (phantom) to be used as the NMR sample. (See 1993 Physics Today letter [4].) It consisted initially of two and later three small separated groups of protons (small pieces of rubber) having numbers of protons in the ratios 3:2:1. The small groups were placed in a straight line parallel to the direction of the linear magnetic field gradient. Thus this MRI sample was one-dimensional. There are very few one-di-



# MRI in the 17th Century

Already in the 17th century MRI was considered to be very helpful in diagnosing the presence of demons in human beings.

**"Exorcism". Etching of the 17th century, Courtesy of Christian Brevard, Bruker SA, Wissembourg**

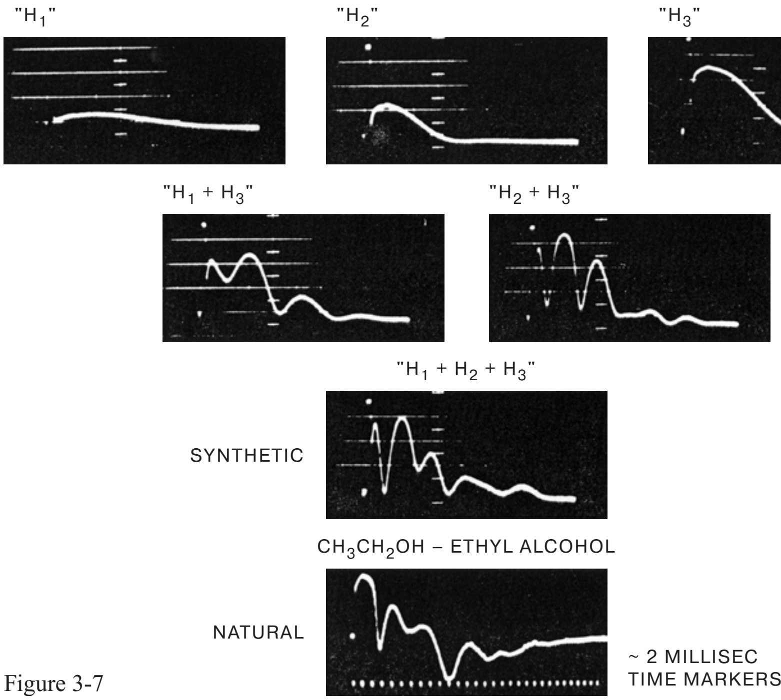



Figure 3-7

mensional MRI samples in medicine, but in physics they are potentially more common. The most notable was used later in the discovery of superfluid helium-3 [5].

The above object was designed to produce, when placed in a linear gradient, a NMR signal similar to that from natural ethyl alcohol. Hence I call it "synthetic ethyl alcohol". If one were using the slower steady-state field-swept NMR technique [6], it would be very easy to understand the NMR signal when the object is in a uniform field. One observes just one line (frequency) with a proton relative signal amplitude of 6. If the object is in a linear gradient we would expect three separate lines with relative amplitudes of 3:2:1.

Using our pulsed NMR technique [7] the nuclear signal is an FID. Again it is simple when the object is in a uniform field – only one frequency with no beat pattern complications in the FID. But if the object is in a linear gradient, the FID will show a beat signal between the 3 groups, all at different frequencies and each group with a different amplitude in the ratios 3:2:1. Such an FID is difficult to understand. The spatial separation between the three coils was set so that the frequency separation between the 3 signals was approximately the same as for the three lines in the field swept spectrum for natural ethyl alcohol. The FID from a similar object would not be difficult to understand if there were only two groups with equal numbers of protons, and even three groups with equal numbers of protons. But for our "synthetic ethyl alcohol" we have three groups, all with different numbers of protons in the relative numbers ratios of 3:2:1. As shown in the observed "synthetic" FID (see figure 3-7 from ref. 1) the observed FID is indeed complicated. In 1952 our pulsed NMR equipment did not yet have computers capable of producing the Fourier Transforms and the images associated with complicated FIDs. But in this "synthetic" demonstration it was not necessary to have such computers with large memories, fast speeds and FFT programs – our image came from visually observing the "synthetic ethyl alcohol" object which had no skull or body cover to conceal its internal structure.

By observing the similarity of the "synthetic" and "natural" FIDs in figure 3-7, it is quickly confirmed that the "natural" FID reveals characteristics of the 3:2:1 internal structure, even though the "synthetic" internal structure is on the macroscopic scale while the "natural" is on the molecular scale.

Most importantly, this demonstration illustrates to the visitor the different parts of pulsed MRI – the linear gradient to obtain spatial correlation, the internal structure of the sample, the FID and the FFT.

Copies of ref. 1 were widely distributed by the Harvard University Library, especially after the publication of ref. 2. Unfortunately, the physics library copy of the thesis was stolen within a year or two, but the distribution was continued by the university's central Widner Library.

In his 1983 book [8], Peter Mansfield wrote that "…although early pioneers in the NMR had come close to MRI, they did not actually do MRI." Perhaps Mansfield was referring to diffusion and flow in internally homogeneous samples. As explained above, without internal structure in the sample, they clearly were not MRI. Except for ref. 4, I did not reply to misstatements in MRI medical papers. But in 1983 I did send a letter to Mansfield calling his attention to the "synthetic ethyl alcohol" MRI demonstration reported in ref. 1. Copies of the letter were also sent to a number of persons who had worked in pulsed NMR and MRI. The reply from one of these early pioneers was particularly clear and succinct: "…the inventor of MRI is the scientist who for the first time applied field gradients to obtain an image of the spatially inhomogeneous spin distribution."

To the best of my knowledge this first occurred, as described above, in my 1952 thesis work [1].

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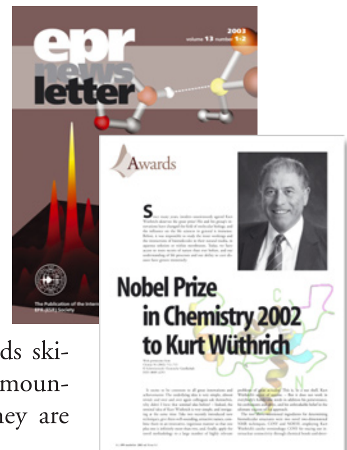
# New Horizons for the Nobel Laureates

You understand that the odds to get a Nobel Prize are infinitesimally small. Under the circumstances it is very interesting to learn what it is to be a Nobel Laureate, how one feels then, and if one just rests on one's laurels enjoying sun, fun and nothing to do. This page shows possible new horizons that opened to Richard Ernst and Kurt Wüthrich after they got their Nobel Prizes. Being from ETH in Zurich, they have to retire at 65 (which is not exactly true for Kurt Wüthrich) and being Swiss (which reads skiing, hiking and mountain climbing), they are still fit for everything.

**Note!** In the *EPR newsletter* 13/1-2 (2003) you find the article "Nobel Prize in Chemistry to Kurt Wüthrich" written by Richard Ernst, the story about a Nobel Laureate written by a Nobel Laureate.




## Richard R. Ernst & Kurt Wüthrich

"James Bond" combat mission of Richard Ernst in the Himalayas triggered his passion for Tibetan art (for details see his article in the "Another Passion" column, this *newsletter*).

For James Bond music, listen to: eprnl.org/bond.mp3

For additional reading, see:
Ernst R.R., Bodenhausen G., Wokaun A.: Principles of Nuclear Magnetic Resonance in One and Two Dimensions. Oxford University Press, Paperback 1990.

For Nobel Prize press release, presentation speech, autobiography, Nobel lecture, interview (video), Nobel diploma, and Prize Award photo, see: eprnl.org/ernst1

007

Kurt Wüthrich realized the desire of every kid to become a circus director. And not only that! He feeds his sea lions with self-caught fish and provides them with a carefully measured portion of vitamins. No wonder, his pets look great!

For circus music, listen to: eprnl.org/circus.mp3

For additional reading, see:
Wüthrich K.: NMR of Proteins and Nucleic Acids. Wiley-Interscience 1986.
Wüthrich K. (ed.): NMR in Structural Biology, A Collection of Papers by Kurt Wüthrich. World Science 1995.

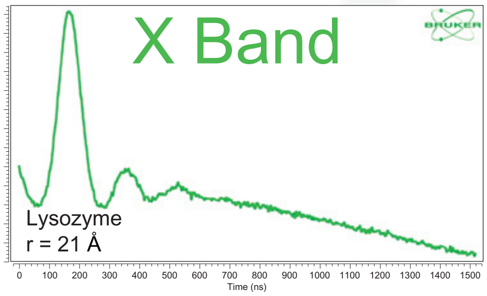
For Nobel Prize press release, presentation speech, autobiography, Nobel lecture (video), interview (video), Nobel diploma, and Prize Award photo, see: eprnl.org/wuethrich1

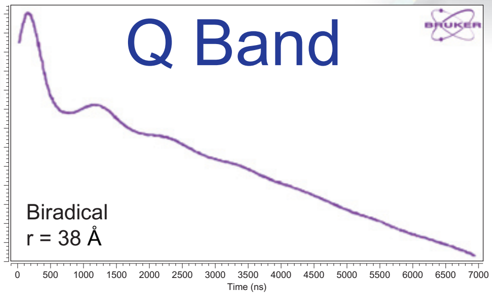
The sea lion photo: ETH Zurich, CC, photographer: Susi Lindig, Zurich

# Revolutionizing Spin Label Pulse-EPR

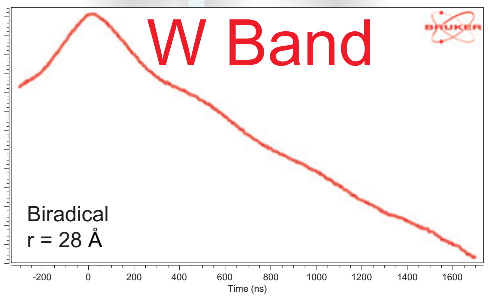
## Multi - Frequency DEER

In collaboration with W. Hubbell

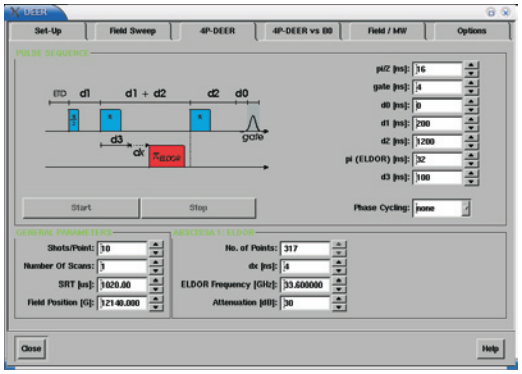


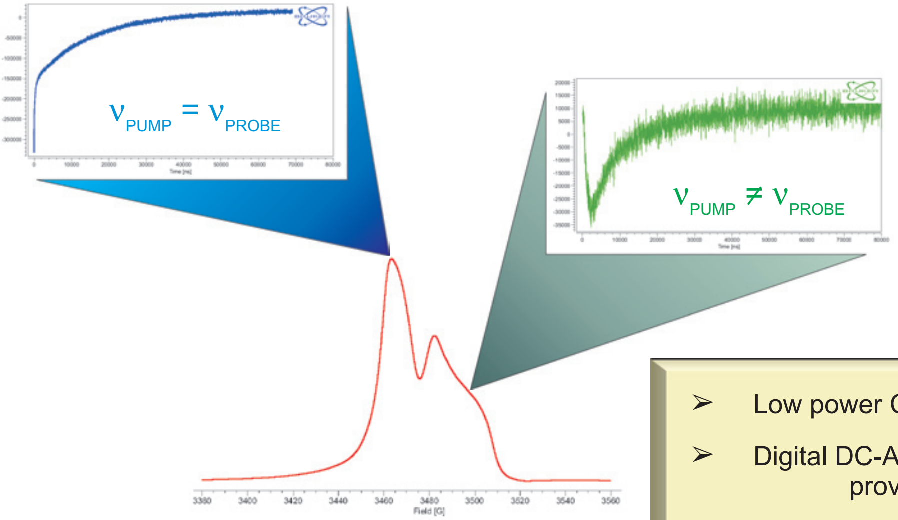

In collaboration with G. Jeschke



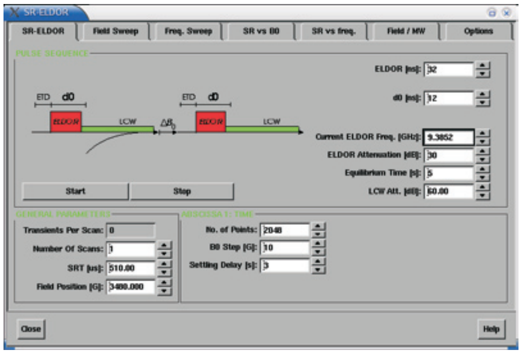

- ELDOR channel - Frequency and Time Sweeps
- ELDOR control - Pulse Tables, PulseSPEL, and Assisted Pulse Experiments
- Multi-Frequency advantage - X-, Q-, and W-band
- Large Bandwidth probes at X-, Q-, and W-bands



## Saturation Recovery ELDOR




In collaboration with P. Fajer



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Another Passion

# Science and *Arts*

## Richard R. Ernst

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We all have become extreme specialists; we all seem to know professionally much about very little. The separation of human activities to the extent we experience it today is a relatively recent 'achievement'. On the other hand, human nature largely remained the same in its complexity and with its very diverse demands. It is, thus, quite natural that professional labour (with the exception of science) has been restricted to 40 or even less hours per week. Nobody should be forced to spend all his lifetime for a specialized professional activity which restricts his range of experiences in a way that impedes the development of his full humaneness. This has its validity for those working on the assembly line as well as for EPR spectroscopists. We scientists know that also scientific work may tend to narrow down our focus of attention if it is performed in exclusiveness.

Science challenges predominantly the human intellect. Although inspiration and creativity are indispensable, it is after all logic, consistency, and experimental reproducibility that determine the value of scientific findings. The personality of the researcher may influence the avenue that leads to the findings, but the final results should no longer reflect their finder's emotions and mentality, except for the fanciful and charming acronyms invented in magnetic resonance!

Scientific work requires enormous self-discipline and restraint in imposing one's own desires and temper upon results. Although also in science, human interactions with all their irrationalities are indispensable, scientists may miss activities that allow for more personal freedom. In general, it is difficult for anybody to walk for an extended time just on a single leg, being a specialist, and it is necessary develop interests in another field as far removed as possible from the professional activities. Two, and even better three legs provide stability. And whenever one leg experiences difficulties, another one may help to overcome the encountered hurdles. It is thus understandable that many scientists develop interests in supplementary fields that appear to be fully unrelated to their professional work and may provide compensation for too much professional focusing. Obviously, a wide range of possibilities for such activities exists, and it is a matter of personal preference which ones are actively pursued.

For many scientists, at first a multitude of sports comes to their minds. Sports certainly may provide an ideal compensation for missing opportunities during the research activities to challenge also the body's functions. In some sports, teamwork is crucial and can lead to an even closer and more playful personal interaction than in science. Going to the limits and testing one's own capabilities can also be challenging, such as in mountaineering or in endurance sports.

Quite frequently, scientists involve themselves in musical endeavours; and indeed there are many gifted performing musicians to be found among scientists. Music has a multifaceted appeal as it simultaneously challenges the emotional and intellectual functions and requires, at the same time, also a refined mastering of bodily coordination. It also provides many opportunities for collaboration in play groups which may lead to unforgettable experiences of emotional synchrony. Perhaps, music stimulates emotionality more directly than most other human activities.

### My Passion for Central Asian Art

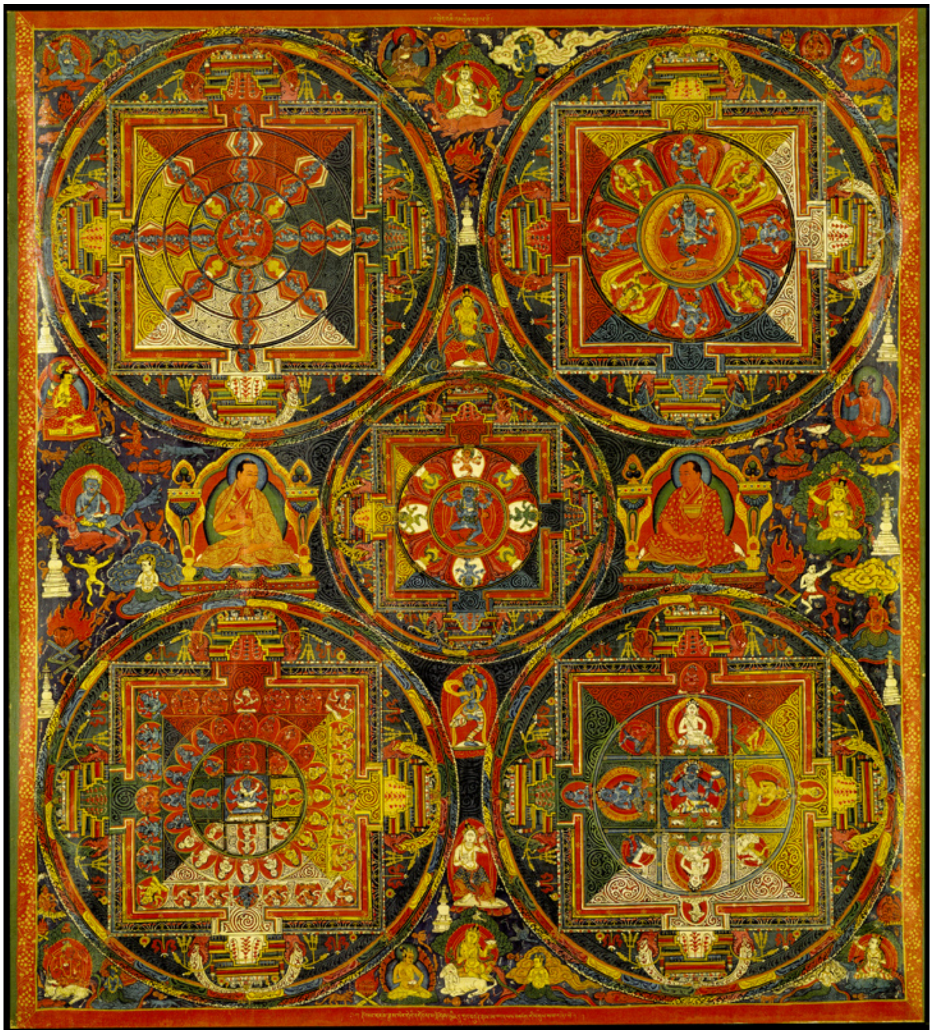
Auxiliary activities often develop from an accidental seed encountered along the path of life, combined with the spontaneous desire to let it germinate in one's own realm. In this manner, also the author's interest in central Asian art developed: a tourist's visit to Nepal, the acquisition of a beautiful thangka, i.e. a Tibetan scroll painting, and the immediate fascination for this colourful painting art formed the germs of a passion that lasted so far for 37 years. The Tibetan involvement ideally served the mentioned objectives: It provided access to a fascinating world probably as remote as ever conceivable from the previous experiences of a technologically interested, narrow-minded Western scientist. It opened insights into dimensions hardly imaginable by rational logics alone. The experience was, so far, truly revealing in a multitude of aspects.

Tibetan culture is unique by its homogeneity, all aspects being dominated by a single spiritual or philosophical concept. Tibetan life and Tibetan culture are through and through Buddhist. Even the most profane deeds are done in direct relation to the teachings of Buddhism. This means that wherever one starts to explore Tibetan culture, it is like drawing at a thread that reveals step by step a multitude of its cultural aspects and it defeats all narrow-mindedness.

The thangka scroll paintings are an ideal entry point as they speak a symbolic pictorial language that can be understood or intuitively felt also by novices. Obviously, the subjects are mostly religious, either evoking deities, or reporting historical facts. Much can be learned from these paintings about the daily life in monasteries and about the historical evolution of Tibetan Buddhism.

Before looking at the bewildering world of Tibetan paintings with its multitude of deities, it is worthwhile to remember that Buddhism is in fact an atheistic religion or philosophy. Buddhists do not recognize the existence of a God, a 'creator' outside of 'creation'. The recognition that all facts and all causes are related is one of the most important insights of Buddhism. Whatever we do leaves its traces. Clearly, this burdens us with responsibility. Although there appears to be evolution, the permanence or the cyclic behaviour of the universe is essential for Buddhists.

Obviously, as in all religions, also in Buddhism there are many levels of appreciation, depending on the degree of insight and the degree of intellectual or emotional involvement. Many devoted simple-minded believers take the apparent deities for existing realities, while the advanced scholars recognize them as mental images of truths that are difficult to express in simple words. For them, the complex Tibetan iconography is in a way a pictorial language for communicating abstract truths of life and death.



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## Ngor Monastery

It was in Tibet, late August 1993, when we left with our four-wheel drive vehicle the main road from Shigatse to Kathmandu and turned left into a side valley with a broad river bed, but without any road. We were told that this is the direction to the monastery of Ngor with its former famous painting school. Our driver did not even know of its existence! So we were rumbling badly shaken across rocks and gravel, through rather deep water, to finally find a hardly visible path going uphill through the rock-covered meadows towards a shabby village, stuck to a mountain ridge. Here, we had to abandon our vehicle and were walking further uphill for another half hour, passing a Tibetan lady washing her long hair bare breasted in a cold mountain stream. Finally, we found indeed the remainders of the previously large monastic complex of Ngor, guarded by a frightfully looking dog and two elderly monks. During the Cultural Revolution it was fully erased, but at least one Prayer Hall was recently rebuilt. But none of the incredibly beautiful Ngor paintings remained. All we found was a printed colour copy of a mandala presently in a collection in Zürich! – It was a sad visit at one of the great power places in Tibet!

## A Fivefold Mandala

A fivefold mandala from the Vajravali series, painted at Ngor monastery probably between 1570 and 1575, is shown in Fig. 1 (see also ref. 1, fig. 91, and ref. 2, items 89 and 90 with an editorial mix-up). The painting forms part of our collection. It was commissioned by the 13th abbot of Ngor, Namkha Pelzang (1535–1602) in honour of the 11th abbot, Sangye Senge (1504–1569). The Vajravali series consists of 26 mandalas, going back to the Indian teacher Abhayakaragupta (11th century). Each of the five mandalas in this painting is devoted to one particular deity (from top left: Buddhakapala (in sexual union), Buddhakapala (alone), Mahamaya, Yogambara, and Jnanadakini). Each mandala is a meditational aid, helping the meditator to concentrate in a lengthy mental procedure on the central deity, penetrating from the outside deeper and deeper into the mandala and into the spirit of accompanying tantra, usually under the guidance of an experienced master. The five mandalas are, so to say, floating among the eight Indian charnel fields, shown in the background, each represented by a stupa, an animal, an Indian yogi, and a fire. By purpose, the meditator has to find its way through this dreadful landscape, where the deceased bodies are offered in pieces to the birds for the final cleanup, to one of the four entrances of each mandala, after having passed a circle of flames and a circle of lotus. Each of the 5 mandalas contains between 4 and 57 additional auxiliary deities. Of the two monks near the centre, the left one represents the founder of the Ngor monastery, Ngor-chen (1382–1444).

For the cursory observer all these details may seem rather confusing and distracting from the apparent beauty of the painting with its strict design but still playful dealing with broken symmetries and colour harmony. Ultimate craftsmanship is essential to lead to such unique pieces of art which never were conceived as art works but rather as meditational tools, and as an homage to a deceased abbot, in this particular case.

Another mandala, a highly complex Kalachakra mandala, painted on the ▶

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same occasion, and contained in the same collection, is shown in ref. 3, fig. 9 and ref. 4, item 237.

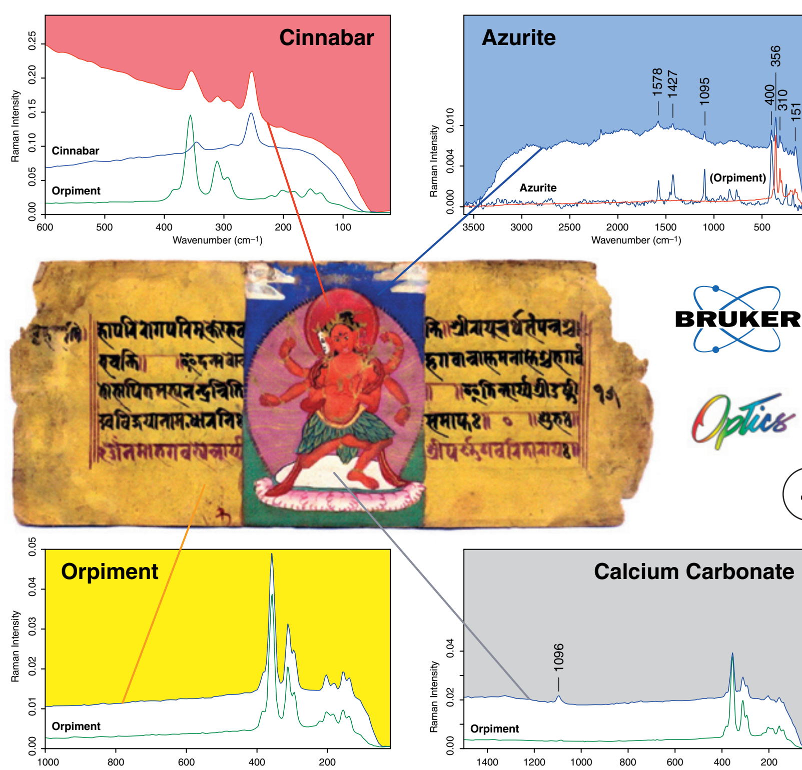
**An Offering Thangka for Mahakala**

About two hundred years later, between 1753 and 1756, the 34th abbot of Ngor, dPal ldan Chos skyong (active 1733–40), undertook a pilgrimage to Eastern Tibet, to Derge. On his way, he gave teachings at various places. And at one of them, he commissioned the painting of Fig. 2. The painting fortunately possesses a covering curtain (not shown) with Tibetan inscriptions accounting for the circumstances of its creation. It is an offering or projection thangka devoted to a special form of the protector deity Mahakala with four arms and four faces. Mahakala is the principal protector of the Buddhist teaching. Mahakala is a powerful deity with a frightful face for frightening the enemies. But he is not shown on this remarkable abstract painting! He is just marked by his emblems, first his head dress with the five sculls, adorned by flaming jewels, below we find his breast coat made out of human bones knitted together. On the upper left and upper right, we find the six bracelets for his four arms and two legs. In the lower part of the drawing, there is an entire arsenal of musical instruments and of weapons, donations to Mahakala offered by the abbot dPal ldan Chos skyong. A six-armed form of Mahakala is shown at the bottom centre of Fig. 3.

Again, this painting has a striking appeal with its masterful distribution of colours and shapes, even when one does not grasp its deeper contents. It is this time painted on a silk scarf, one of those being usually presented upon a visit to a respected person. Here, it is meant to be a sacrifice to Mahakala. There is also a Tibetan prayer woven into the silk.

**Gayadhara and Drogmi**

The painting of Fig. 3 stems again from Ngor monastery and was painted nearly at the same time as the five-fold mandala of Fig. 1 at the end of the 16th century. It tells us about the history of the Sakya school to which the Ngor monastery belongs. The Sakya monastery, which gave the school its name, was founded in 1073 by Konchog Gyalpo. At its time, the Sakya school was politically leading in Tibet, and its most important leader, Sakya Pandita (1182–1251) had to negotiate with Cinggis Qan (1155–1227) in order to prevent a Mongolian invasion of Tibet. The later Chinese Emperor Khublai Khan, also of Mongolian origin, felt much attracted by the tantric Tibetan Buddhism with all its glamour and its mys-

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teries, and he invited Phagpa (1235–1280), the nephew of Sakya Pandita, to his court in Peking. And indeed, the latter became a very close friend and advisor of Emperor Khublai Khan. In this way, nominal jurisdiction over entire Tibet was offered to Phagpa and his Sakyapa school. In later times, several further Chinese Emperors felt attached to Tibetan Buddhism and many traces are still left in the Forbidden City.

In the center of Fig. 3, we find Drogmi 'the translator' (992–1072), the teacher of Konchog Gyalpo, and on his right Gayadhara (994–1043) with the red hat. Gayadhara, a Buddhist monk from Kashmir, brought the important 'Lamdre' teaching to Tibet and Drogmi translated it into Tibetan. They are most influencial links in the Sakya lineage of teachers, forming the spiritual descendents from the primordial Buddha Vajradhara, shown in upper left corner of the painting. He is then followed by a series of Indian yogis and Tibetan monks that form an unbroken lineage to the last monk in the lower right corner who is responsible for the ceremony in honour of the two central teachers.

The painting shows between the two the much revered teachers, as a tiny figure, the originator of the 'Lamdre' teaching, the Indian Mahasiddha Virupa (9th c.) who pawned once the sun to pay his personal debts so that the sun could not move for two days. Above him is the powerful protector Yamantaka, the conqueror of death with his nine heads. As described in ref. 3, the ninth head is the one of Manjusri, the deity of wisdom. This shall be a reminder that Yamantaka is in fact a representation or an incarnation of Manjusri, bringing together wisdom and the power to overcome death, perhaps a convincing symbol of our own endeavours in science. In the lower centre, one finds a six-arm Mahakala as a protector of the teachings (similar but not identical to the four-arm Mahakala evoked in Fig. 2), surrounded by some further deities.

## Classification of Thangkas

Obviously, it is impossible to give a survey over the enormous multitude of Tibetan thangka paintings by just three examples. Besides the Sakya school, there are the equally important schools of the very conservative Nyingma, the widely branched Kagyu, and the reformed Gelug schools. They all have produced a wide variety of thangka paintings.

One may perhaps divide roughly thangkas into those that represent deities and those that describe historical personalities and historical events, although even this division is not simple as there are many deified historical figures.Thangkas of deities can again be divided into those representing peaceful deities, such as Buddhas, Bodhisattvas, Arhats, and Mahasiddhas, all of them represented in normal human form. But equally important are the representations of the frightful protectors, often with additional extremities, heads, and a third eye. Often they are shown on a black background and are then banned to special temples, not accessible to the general public which might too much be frightened by them. In addition, there are tantric deities connected to specific tantric teachings which have to be evoked through meditation during a meditational procedure. Examples are Guhyasamaja, Kalachakra, and Hevajra, all of them shown with numerous arms, legs, and/or heads. Finally, mandalas are special forms of meditational helps.

## Thangka Painting, Analysis, and Conservation

Thangka paintings are delicate works of art that often have been treated quite roughly during their daily usage in monasteries and homes. Their state of preservation is not always satisfactory and may need conservational activities. Obviously, this calls for some basic knowledge on the painting process.

The thangka painting starts by stretching a piece of cotton on a wooden frame support. It is then grounded by several layers of chalk mixed with a weak hide glue solution that is dried at the sun and then smoothed by rubbing it with a flat stone. The design of the painting usually requires a geometric construction procedure following fixed rules to achieve proper proportions especially of the central figure(s). After this has been applied by pencil lines, the free hand drawing is sketched again by pencil, making when necessary corrections. The final contours are then marked by black ink lines. Now follows the application of the mostly mineral pigments, again mixed with hide glue, often after having marked the area to be coloured by a colour-specific letter code. At the end follows the shading of the still rather dull looking larger areas, the application of gold lines and items, and the insertion of the eyes by a master painter.

Before any conservational action, the pigments need to be analysed. Sometimes, it is requested that all restorations need to be made reversible. This is particularly important for large-area restorations where usually foreign pigments are used that can easily be distinguished from the original material. However for very small-scale corrections it is often better to apply the correct pigments in a way that needs no further distinction between new and old.

Pigments can often be analysed by simple chemical reactions, performed on tiny samples taken from the painting by careful probe taking, usually at already damaged positions. The chemical analysis under the microscope can easily be performed on particles with a diameter of about 50 μ. A chemical analysis is normally restricted to determining the metal ions contained which is often, but not always, characteristic enough. The analysis of the samples can also be performed by X-ray fluorescence or Raman spectroscopy. Here is a list of some of the most frequently found pigments in thangkas: Green: Malachite, $CuCO_3Cu(OH)_2$. Blue: Azurite, $2CuCO_3Cu(OH)_2$; Prussian blue, $Fe_4(Fe(CN)_6)_3$; Smalte, Cobalt glass; Indigo, $C_{16}N_2O_2H_{10}$. Yellow: Orpiment, $As_2S_3$. Red: Cinnabar, HgS; Minium, $Pb_3O_4$.

Naturally, a non-invasive, non-destructive in-situ analysis by spectroscopic means would be more desirable. Today the most suitable technique is infrared Raman spectroscopy. It can be well be used in reflection and allows one to differentiate between most pigments quite characteristically. Figure 4 shows an illuminated page from a Nepalese Newari manuscript (18th century). The four in-situ recorded spectra allow one to identify the red pigment cinnabar, the blue pigment azurite, the yellow pigment orpiment, visible in all areas, that is used to colour and protect the paper, knowing that orpiment with its arsenic content is an effective rat poison, and the white pigment calcium carbonate. The recordings were performed by Ms. Carolin Lehner at Bruker Optics, Ettlingen, using an FT-Raman-Module FRA106/S, alternatively with the object in the sample chamber or externally by means of a fibre optics probe.

Another passion can indeed open entirely new worlds to a narrow-minded physical chemist and stimulate his mind in a way that he never would like to miss again. For further information, the interested reader might consult refs. 1–5.

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# Solutions For EPR Imaging

## L-Band Imaging - Biomedical Research

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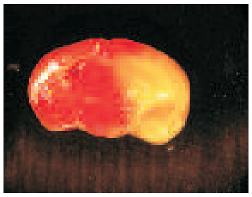
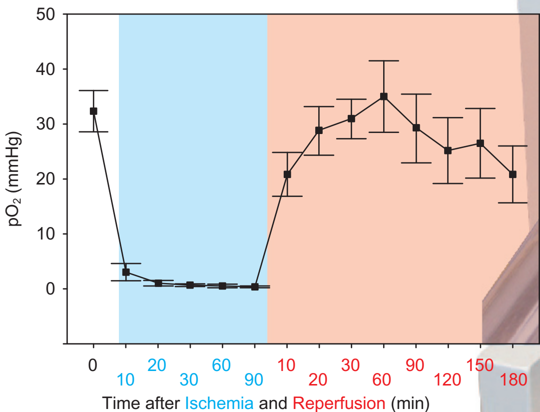


Histological Image
Red = viable tissue
Yellow = dead tissue

*in vivo* EPR Image

Ischemic Core $pO_2$ Changes

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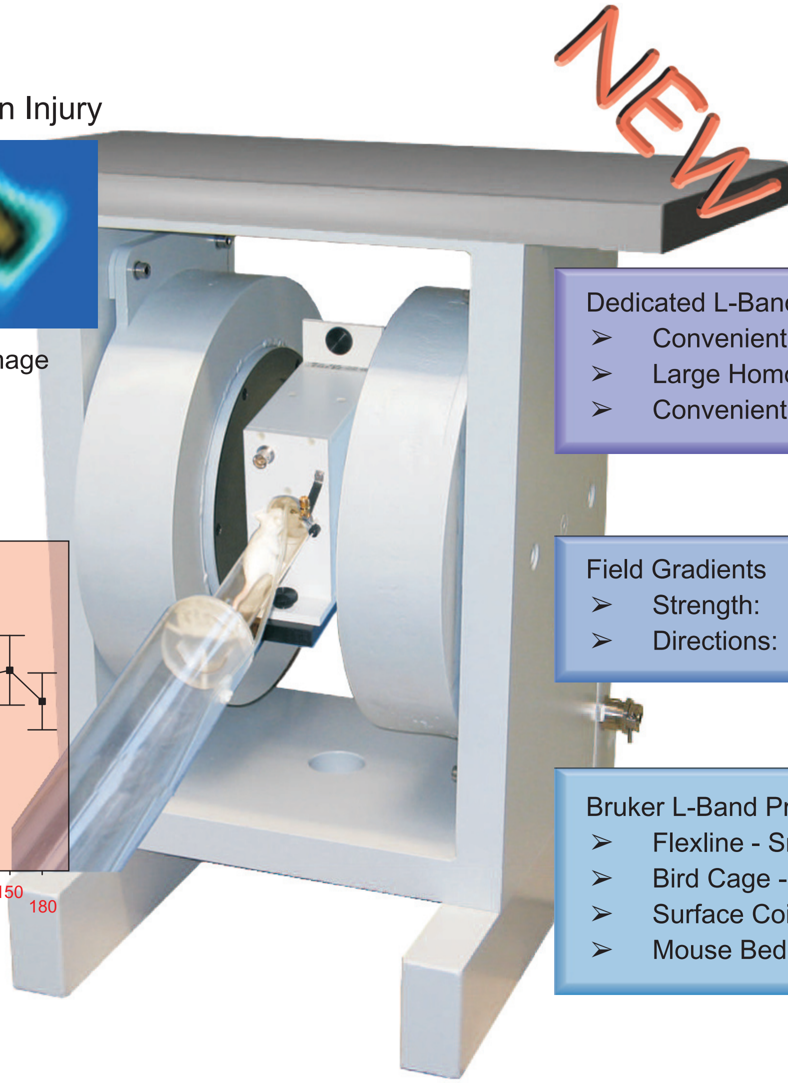


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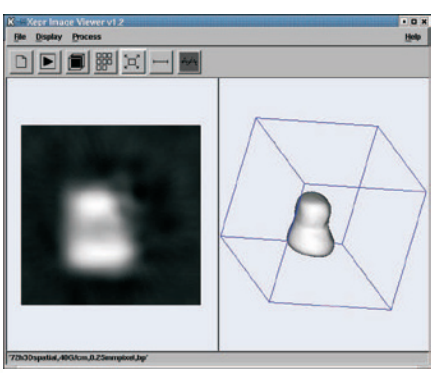
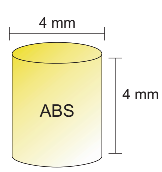
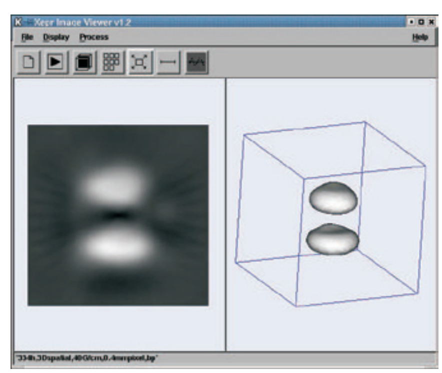


After 3 days



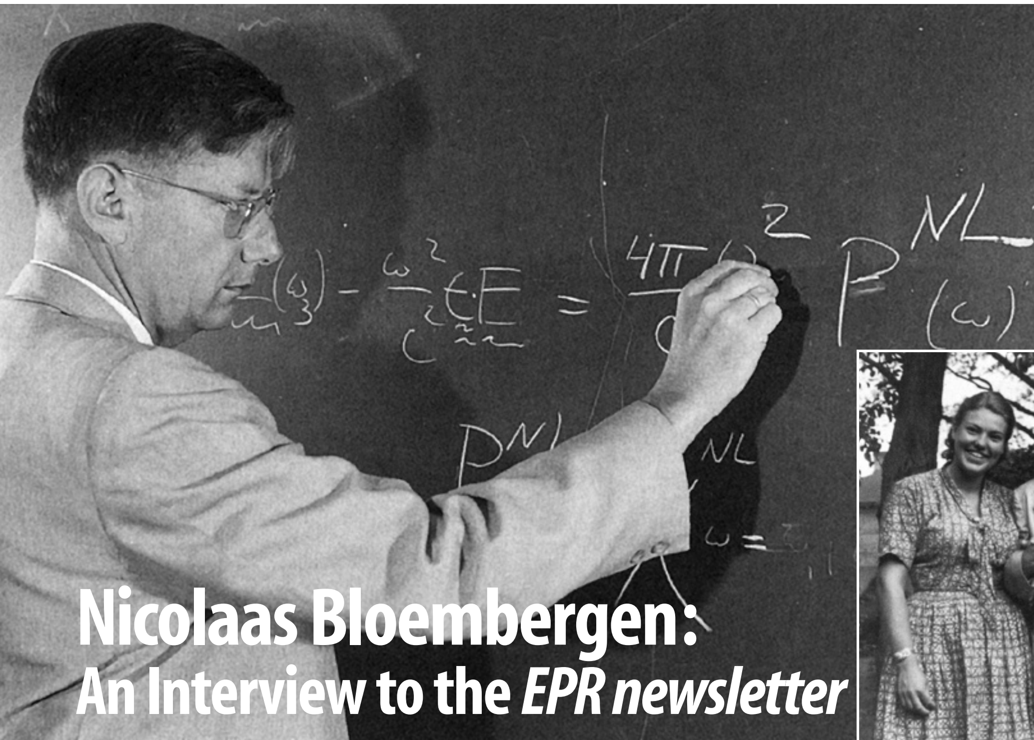

Heat Treatment at 393 K

Radicals derived from polymer stabilizer



After 14 days

# Nobel Laureates Doing EPR



## Nicolaas Bloembergen: An Interview to the *EPR newsletter*

**EPR newsletter:** ***Dear Professor Bloembergen, on behalf of the readers of the EPR newsletter we are most appreciative that you agreed to answer the questions of this interview. It is an axiom that no recognition is more highly regarded in our modern world than the Nobel Prize. What is it to be a Nobel laureate?***

**Nicolaas Bloembergen:** In the sciences of physics, chemistry and physiology the Nobel prize is indeed the most prestigious honor. I do not know how the Nobel prize is regarded in the fields of literature and peace. The fields of mathematics and biology have other prestigious prizes. It is nice to receive this recognition, but one should be careful about being considered an expert in other nonrelated fields.

***In your Nobel banquet speech you emphasized the fact that science readily crosses international boundaries. At the same time, many scientists are anxious about the so-called brain drain. What do you think about this?***

In the long term brain drain is not a serious issue. Many scientists, having been trained abroad, return to their native country. I would say that Europe is now on a par with the USA. The disparity which existed immediately after World War 2 has disappeared.

***Thanking the Nobel foundation for the award, you said that you accept the honor together with the responsibility. What is your idea of responsibility of a scientist?***

It is the responsibility of a scientist to call attention to the misuse or misrepresentation of science by politicians for political purposes, or by less conscientious scientists for personal reasons.

***I would like you to tell us about one of the most-cited physics papers, commonly referred to as BPP (N. Bloembergen, E. M. Purcell and R. V. Pound, Phys. Rev. 73, 679, 1948). Could you please recollect the atmosphere of working together with Purcell and Pound on this paper?***

I was fortunate to become the first graduate student of Professor Edward M. Purcell at Harvard University in the spring of 1946. He, Bob Pound and I had many exciting discussions that year about motional narrowing in NMR. Purcell and Pound showed how the resonance fine structure due to spin-rotational interactions, observed by Rabi and associates in a hydrogen molecular beam, collapsed to a single resonance due to collisions in hydrogen gas, and caused "pressure narrowing" of this resonance. Pound's interest then shifted to the design and construction of a tunable rf oscillator. He used this "Pound box" to study quadrupole splittings of NMR in crystals. I did most of the experimental and theoretical work on the NMR in liquids, described in the BPP paper. Purcell was a very stimulating leader and he was generous in giving credit to others. My early work in NMR in 1946 and 1947 is described in volume 1 of the encyclopedia of NMR, edited by D. M. Grant and R. K. Harris, Wiley, 1996 on pp. 220–225. The BPP work is also discussed in detail in the volume I edited "Encounters in Magnetic Resonance", World Scientific, Singapore, 1996.

***We know you did quite some EPR in your research. What do you think about the role and place of EPR as a method to study matter?***

This same volume reprints and discusses some of my work in EPR. Of course the most influential paper is "Proposal for a new type solid state maser", Phys. Rev. 104, 324–327, 1956. This paper also stimulated the developments of lasers.

***What do you think about the success of NMR in imaging and protein structure determination: a normal evolution, an unexpected surprise or whatsoever?***

Neither Purcell nor I had any inkling in the late forties about MRI. This unforeseen development during the seventies was an unexpected surprise for us. I am pleased that my early data on proton spin relaxation times in water and aqueous solutions are quite relevant for the resolution obtainable in MRI imaging. I greatly admire the progress in this field.

***I am greatly impressed by your words that the enduring encouragement of your wife Dell has contributed immensely to the successes of your career. Do you think a man has to be married happily to reach the heights in his career? A "lone wolf" is doomed to failure?***

There are greater scientists, including Newton and Einstein, to show that "lone wolves" are not doomed to failure. In my case the support of my wife was most helpful in my scientific career.

***In your autobiography you tell about the periods of relaxation in your youth devoted to sports and that you attempt to keep the body fit by playing tennis, by hiking and by skiing. Could you please tell us about a memorable hiking in your life.***

My hiking experiences, many long ago with our young children, are not memorable, but I may mention a hike my wife and I made just three years ago, when we had retired from Massachusetts to Tucson AZ. We went to Picachu Peak State Park to see the desert in bloom. We scaled a rather steep trail to a saddle point. On the other side the descent was unexpectedly still steeper. At a few vertical points one had to grab steel cables with both hands and find some toeholds in the vertical rock. My wife, who had undergone serious surgery the year before was furious, but she nevertheless had the presence of mind to ask me to take a picture, while she was dangling from the steel cables. It serves as proof of my irresponsible action.

***You are Dutch by birth and American citizen since 1958. You traveled a lot and visited different countries and got acquainted with different cultures. What part of your personality is Dutch and what is American and what belongs to the rest of the world?***

Both my wife and I feel more at home in the USA than in the Netherlands. Nevertheless we retain many Dutch personality traits and the Dutch accent in our pronunciation of English remains evident. We enjoy meeting with our former students, associates and colleagues in many different countries. My activities in science and my wife's activities in art and music have an international character.

***You say that the contact with the younger generations keeps the mind from aging too rapidly. In turn, it would be nice if the younger generation and all readers of the EPR newsletter could benefit from the unique possibility to listen to you. In your feeling, what makes a good scientist?***

You have to be curious and interested in posing and studying scientific questions. You must also have the motivation and the endurance to overcome inevitable periods of disappointment. With some luck your peers will hold you in high regard.

# K. Alex Müller:
## An Interview to the *EPR newsletter*

**EPR newsletter:** ***Dear Professor Müller, on behalf of the readers of the EPR newsletter we are most appreciative that you agreed to answer the questions of this interview. It is an axiom that no recognition is more highly regarded in our modern world than the Nobel Prize. What is it to be a Nobel laureate?***

**Alex Müller:** When a person is awarded the Nobel Prize he becomes a public figure. In this respect it is quite different then when one is a scientist even maybe well known to colleagues, also globally. As a public figure, one has the possibility to influence decisions of politicians regarding science. What concerns myself, I was in charge of a commission to promote the so-called Swiss light source, a synchrotron with energy above 2 GeV. This large instrument is now in operation since two years, doing research from biology to condensed matter physics and microelectronics, and is a substantial success. Therefore, I was able to capitalize on my prize to the benefit of a younger generation of scientists.

***How can you explain the fact that la bella Svizzera, the precious gem in the heart of Europe, has the highest ratio of the number of the Nobel Laureates to the total number of its citizens?***

Well, I think it is not because the average intelligence quotient of the Swiss is higher than elsewhere. However, in my relatively firm opinion this is based on the excellent schooling, starting from the kindergarten to the elementary classes. Here, the tradition in Switzerland is very old, over 200 years, and is connected with the famous teacher Heinrich Pestalozzi.

***You shared your Nobel Prize with Georg Bednorz and in your autobiography you mention his fundamental insight into materials, his human kindness, his working capacity and his tenacity of purpose. Could you please share with us your understanding of team work?***

In 1983 after a presentation of Professor Harry Thomas, who postulated the existence of so-called Jahn-Teller polarons in condensed matter, I conceived the idea to use the possible existence of such quasi-particles to enhance the transition temperature of superconductivity. I talked to Georg Bednorz and was able within two hours to assure his collaboration. So we formed a team in which mutual respect of each other's capability was essential. This even at times where the possible success looked rather dull. In such circumstances it is important to continue and not lose the goal out of sight. In this respect the road one pursues is important because one does not know whether one reaches the goal or whether one goes well beyond it.

***Could you please recollect the day when you observed high-temperature superconductivity for the first time?***

The observation of high-temperature superconductivity was found in an experiment around Christmas-New Year by Georg Bednorz. I was in ski vacation at that time. When I came back, I was very happy on the one hand, on the other hand, we asked ourselves whether there could be some other effect which was showing the drop to zero resistance in the compounds. Only when we had measured the susceptibility three or four months later we were sure we were correct.

***We know you did quite some EPR in your research. What do you think about the role and place of EPR as a method to study matter?***

I have done EPR by now for over five decades with several hundreds of publications. I consider EPR as a very powerful tool to study condensed matter physics. In the moment one observes an EPR line one is in a position to understand a lot. A large part of my EPR work were in oxides. For instance, I studied by EPR relaxation rates, which show the Jahn-Teller effect. I followed this line for over 10 years and therefore I understood that the Jahn-Teller stabilization energies for Ni(III) and Cu(II) are the largest ones and this is why I suggested to Georg Bednorz to use crystals which contained these ions. It was Cu(II) with which we finally succeeded.

***When I first tried to contact you, I was told you are skiing in the Alps. Then I read in your autobiography that since your childhood you were very active in sports, especially so in alpine skiing. What is it in alpine skiing that attracts you so much?***

Yes, skiing is my favorite sports. I learned skiing before I learned swimming. When I was a student I participated in the ETH-University of Zurich down hill racing competition and in slalom and was quite successful. In ski sport there are two aspects. First of all, to really master the technique and the rhythmic swinging down and secondly the landscape around you which in the Alps in general is beautiful, it changes all the time and is rewarding by itself. I am now 77 years old and go to ski every winter between 25 and 30 days.

Coming to dreams: all people dream, whether they are aware of it or not. My best dream is to ski down a virgin snowfield. When I dream in this way, which is not often the case, I know that everything in my psyche is all right.

***Upon completion your basic military training in the Swiss army, you enrolled in the famous Physics and Mathematics Department of the Swiss Federal Institute of Technology (ETH) in Zurich. You took courses and examinations of Wolfgang Pauli. You say he was truly a wise man with a deep understanding of nature and the human being. What was his impact on your further development as a man and a researcher?***

It is difficult to answer in such an interview the importance which Wolfgang Pauli had on me. In short, Wolfgang Pauli was from the point of view of physics of course a genius. For instance, Pauli was the founder of condensed matter physics, because he calculated the susceptibility of Fermionic particles. I learned from him how a proper assumption through calculations gives a correct answer. On the other hand, Pauli had, what is less known to physicists, a deep and substantial understanding on the subjective part of the human being, including the subconscious*. When in 1952, I made my examinations for the diploma at the ETH (I was examined by Pauli in theoretical physics), the famous article of Pauli on the archetypical views of Johannes Kepler existing before his epochal discovery of planetarian motion was accomplished. So, Wolfgang Pauli was a man who saw both borders of the river, so to speak. With this I mean he saw the border of objective science and the border of the river representing subjective transcendental aspects. Wolfgang Pauli asked the question what is behind these two states of being, which are obviously complementary to each other, just think of momentum and location of an elementary particle, as emphasized by Niels Bohr.

***What is the driving force for you in your research?***

This is a difficult question to answer. It is in part related to my answer to the previous question. I have preexisting views you may call it intuition, and I am driven to find out what is the reality.

***I heard that you like old American cars and are proud to drive such an "Oldtimer". What is it that fascinates you in these cars?***

By now my old cars are European cars. I own two Oldtimer Jaguars and one Alfa Romeo. I am not only driving these cars, but I also work on them, i.e., I maintain them. What fascinates me?! A car is, on the one hand, a product of rationalistic engineering and on the other hand its appearance outside is a work of art, therefore it is a synthesis of the two worlds I have discussed above regarding to the question about Wolfgang Pauli.

***The words "one should look for the extraordinary" ever-repeated by Dr. H. Thiemann made a lasting impression on you. What would be your message to the younger generation and all readers of the EPR newsletter?***

The expression of Doctor Thiemann that one should look for the extraordinary is very important and general. It relates to science, engineering and aspects of art. For instance, ancient and modern paintings. If one succeeds, in these times of prevailing egalitarian approaches in general behavior, to open the eyes of the younger generation to the extraordinary perspective, one may be able to bring back elitist approaches, which in my opinion are important as well.

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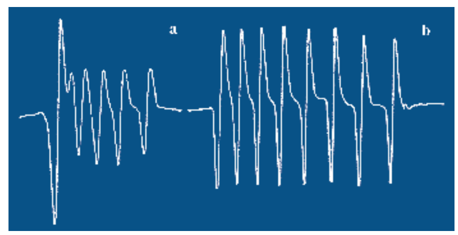
* See also "For Your Perusal" in this issue.

# EPR Research of Nobel Laureates

As you all know, up to now no Nobel Prize went out to award research done by means of EPR. However, a number of the Nobel Laureates made use of EPR during their scientific career. Who are they, what did they study, and what kind of role did EPR play in their research? These are the questions to be addressed in the following short essay.

**Aleksandr M. Prokhorov**

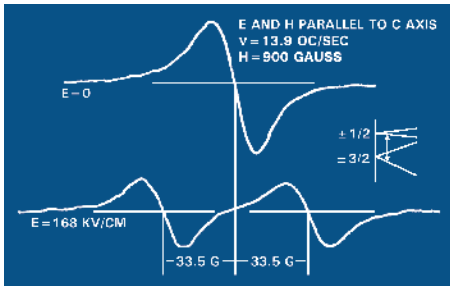
In 1964 Aleksandr Prokhorov, together with Nikolai Basov and Charles Townes, received the Nobel Prize in Physics for "fundamental work in quantum electronics that led to




the construction of oscillators and amplifiers based on the maser-laser principle". To make this breakthrough possible, the prospective materials for lasers and masers had first to be found and their properties had to be characterized thoroughly. Between 1955 and 1970 Aleksandr Prokhorov used EPR, mainly in collaboration with G. M. Zverev, to study the magnetic parameters and the relaxation times of single crystals doped with various transition metal ions. By 1957 Aleksandr Prokhorov had discovered that ruby would make a suitable laser material. The sketch shows the EPR spectra of two Co(II) centers in sapphire recorded at a temperature of 4.2 K [1].

**Nicolaas Bloembergen**

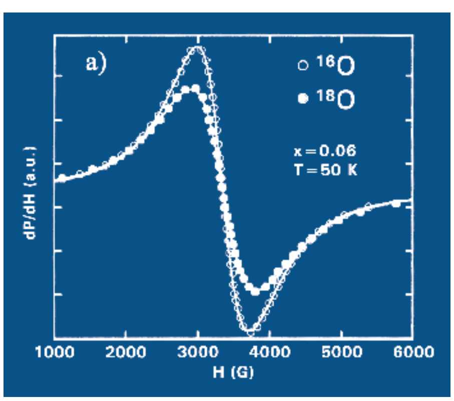
After more than one decade of research in magnetic resonance, Nicolaas Bloembergen switched between 1960 and 1965 completely to nonlinear optics. "For his contribution to the development of laser spectroscopy" he got in 1981 the Nobel Prize in Physics. His research in magnetic resonance is collected and commented in ref. 2. Some of the early studies in magnetic resonance were devoted to EPR investigations related to the development and characterization of maser materials and to the electric field shift that can be




observed in EPR spectra. The sketch shows the splitting of a line in the EPR spectrum of ruby caused by a strong external electric field [3].

**K. Alex Müller**

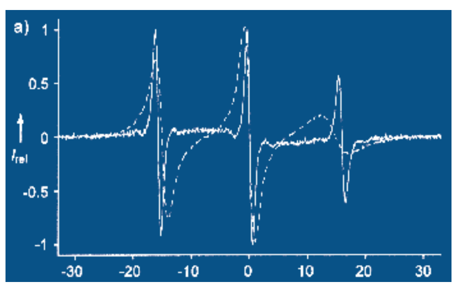
EPR spectroscopy runs all through the biography of Alex Müller, who got the Nobel Prize in Physics in 1987 together with J. Georg Bednorz "for his important breakthrough in the discovery of superconductivity in ceramic materials". Already during his PhD thesis carried out under the supervision of Professor Busch at the Laboratory for Solid-State Physics at ETH, Alex Müller made his first acquaintance with EPR: In his dissertation, defended in 1958, he studied the at that time newly synthesized double-oxide $SrTiO_3$. During the whole research career, which he mainly spent at the IBM Zurich Research Laboratory, Alex Müller abided by EPR as an important tool to characterize materials, in particular $SrTiO_3$ doped with different transition metal and rare-earth ions. He studied chemical bondings, ferroelectric and soft-mode properties, as well as multicritical phenomena of structural phase transitions.




After his discovery of the high-$T_c$ superconductors in 1986, he demonstrated that EPR can also successfully be used to characterize these new materials. This is reflected in the title "Insights into oxide-superconductors using EPR" of his plenary lecture presented at the 31st Congress Ampere in Poznań in 2002. In a recent paper on high-$T_c$ superconductors [4], the authors write: "…The investigation of high-$T_c$ superconductors has, from a magnetic resonance point of view, until recently been dominated by nuclear magnetic resonance (NMR). The observation of electron paramagnetic resonance (EPR) is of great interest, because the time domain of observation of EPR is two to three orders of magnitude shorter than that of NMR. However, the application of EPR to high-$T_c$ cuprates was restricted owing to the absence of intrinsic EPR signals in these compounds. The reason of the EPR silence in the cuprates is due to the extremely large linewidth, which is estimated in the present study. The situation has improved recently, when the EPR from trapped three-spin polarons was observed in $La_{2-x}Sr_xCuO_4$, in which the presence of Q2-type Jahn-Teller (JT) polarons were identified…" The sketch shows the EPR signal of $^{16}O$ and $^{18}O$ samples of $La_{1.94}Sr_{0.06}Cu_{0.98}Mn_{0.02}O_4$.

**Kurt Wüthrich**

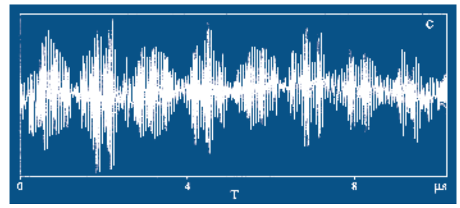
Similar to Alex Müller, also Kurt Wüthrich started his scientific career with a PhD thesis, where he extensively used EPR spectroscopy. He finished his dissertation with the title "Katalyse der Autoxydation von o-Phenylendiamin durch Kupfer(II)-Ionen in wäss-




riger Lösung" (Catalysis of the Autooxidation of o-Phenylenediamine by Copper(II) ions in Aqueous Solution) carried out under the supervision of Professor Fallab at the University of Basel, in 1964. After his graduate studies, Kurt Wüthrich concentrated for another year on EPR studies, in particular on copper and vanadyl complexes in liquid and frozen solutions. Later, he also used EPR during his postdoctoral training at the University of California, Berkeley, to study the hydration of metal ions and metal complexes. In 1967 he started research on hemoproteins where also some EPR was involved. Very recently, Kurt Wüthrich started to use paramagnetic reagents in NMR studies of membrane protein-lipid interactions in mixed micelles, where he applied EPR (sketch) to determine the rotational correlation times of the spin probes [5].

**Richard R. Ernst**

Apart from some other passions, like music and Tibetan art (see this issue), Richard Ernst concentrated his creative power mainly on nuclear magnetic resonance, and since he is




emeritus, also on science policy. However, because his research in pulsed NMR was extremely successful, he became interested in applying a similar kind of methodology and related mathematical formalisms also to EPR. Between 1985 and 1992, he published a series of papers, together with Arthur Schweiger and other members of his research group, which were devoted to subjects like phase cycling in EPR, new ESEEM approaches and pulsed ENDOR schemes, reduction of deadtime problems and longitudinal detection, to mention a few. The sketch shows a time trace recorded with the so-called "soft-ESEEM" technique, which among other advantages, can be carried out with much less microwave power than the one required for standard ESEEM experiments [6].

EPR as a method to investigate matter needs no bush. The EPR community knows its vast possibilities and intensively makes use of them in studying various problems. The above synopsis shows the Nobel Laureates in their "EPR" colors adding a new dimension to their multi-dimensional personalities.

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2. Bloembergen N. (ed.): Encounters in Magnetic Resonances: Selected Papers of Nicolaas Bloembergen (With Commentary). Singapore: World Scientific Pub Co Inc 1996.
3. Bloembergen N., Royce E.B in: Low Symposium on Paramagnetic Resonance (Low W., ed.), vol. 2. New York: Academic Press 1963.
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5. Hilty C., Wider G., Fernandez C., Wüthrich K.: ChemBioChem **5**, 467 (2004)
6. Hustedt E.J., Schweiger A., Ernst R.R.: J. Chem. Phys. **96**, 4954 (1992)

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Notices of Meetings

## A Workshop
## *Distance Measurements by ESR*

The National Biomedical Center for Advanced ESR Technology (ACERT) at Cornell University, Ithaca, USA
August 7 and 8, 2004

The National Biomedical Center for Advanced ESR Technology (ACERT) at Cornell University will be conducting a workshop on "Distance Measurements by ESR" on August 7th and 8th, 2004, as the second in its ongoing series of instructive sessions on modern ESR. The workshop will include lectures, demonstrations, and "hands-on" experience with the latest ESR methods for measuring distances, with special emphasis on the modern pulsed methods including: Double-Quantum Coherence (DQC) ESR and Pulsed-ELDOR.

**For further details regarding this workshop, please contact:** Heather Foringer (hef8@cornell.edu), Administrative Manager, ACERT, Cornell University.

## The Conference
## *Nanoscale Properties of Condensed Matter Probed by Resonance Phenomena* (NanoRes-2004)

Kazan, Russian Federation
August 15–20, 2004
www.mi.ru/~dtayursk
(previously announced in *newsletter* 13/4)

## The 14th Annual Conference
## *Modern Development of Magnetic Resonance* ($EPR_{60}$)

Kazan, Russian Federation
August 15–20, 2004
www.kfti.knc.ru/EPR60
(previously announced in *newsletter* 13/4)

## Workshop on EPR Studies of Viable Biological Systems, (especially in vivo) and Related Techniques (especially oximetry)

Hanover, New Hampshire, USA
September 19–23, 2004
www.dartmouth.edu/~eprctr
(previously announced in *newsletter* 13/4)

## The 6th Workshop on Applications of EPR in Biology and Medicine

Krakow, Poland
October 5–10, 2004
www.mol.uj.edu.pl

This international meeting will cover recent advances in the field of biophysical and biomedical applications of EPR spectroscopy, spin trapping and imaging, including digital detection, high-frequency applications (W-band and higher), low-frequency applications both in vivo and in vitro, detection of oxygen and nitrogen radicals in oxidative stress, site-directed spin labeling, structural biology applications, metalloproteins, membranes, light-induced free radical transients and others.

**For further information, please see the web site or contact:** T. (Tad) Sarna, PhD, DSc, Chair, B. (Raman) Kalyanaraman, PhD, Co-Chair, Scientific Program Committee, e-mail: epr@awe.uj.edu.pl

## ISMAR 2004

Jacksonville, Florida, USA
October 24–29, 2004
www.ismar.org
(previously announced in *newsletter* 13/1-2)

## The Asia-Pacific EPR/ESR Symposium 2004 (APES'04)

Bangalore, India
November 22–25, 2004
physics.iisc.ernet.in/~apes04
(previously announced in *newsletter* 13/4)

## International School on EPR Spectroscopy and Free Radical Research (ISEPR-APES'04)

Mumbai, India
November 17–20, 2004
www.ied.edu.hk/has/phys/apepr
(previously announced in *newsletter* 13/4)

## photo of the issue

Wolfgang Pauli (left) and Niels Bohr (right) playing tippe top

eprnl.org/top.mpg

PHOTOGRAPH BY ERIK GUSTAFSON, COURTESY AIP EMILIO SEGRE VISUAL ARCHIVES, MARGRETHE BOHR COLLECTION

Conference Reports

## The 42nd Annual Meeting of the Society of Electron Spin Science and Technology (SEST2003)

Hiroshima, Japan
October 29–31, 2003

The 42nd annual meeting of the Society of Electron Spin Science and Technology (SEST) was held in Hiroshima, Japan, on October 29–31, 2003. The meeting was organized by Prof. Masaru Shiotani and the meeting site was in the Hiroshima University main campus located about 40 km east of the downtown of Hiroshima City.

SEST was newly found in October 2002 by a unification of two Japanese ESR groups, namely, the Japanese ESR symposium group and the in-vivo ESR group, which had their own history of 41 and 7 years, respectively. The society aims to be a base for providing information on electron spin science and technology, and the meeting SEST2003 was held as the first memorable annual meeting after the foundation of SEST.

The scientific program consisted of nine special invited presentations (one from Sweden, one from UK, one from Italy, one from Germany, one from USA, two from Russia, and two from Japan), 64 oral presentations, and 73 poster presentations. 205 scientists participated at this meeting. Topics related to the following subjects were presented and discussed: electron spin magnetic resonance and electron-spin-based science and technology in a variety of pure and applied natural sciences covering chemistry, physics, materials science, spin-mediated magnetic field effects, in-vivo applications and bio-medical imaging, environmental sciences, dosimetry and archeological applications, with repect to both theoretical and experimental aspects. Interestingly, about one third of the participants were graduate students. I am very pleased to say that the meeting seems to be attractive and interesting for young scientists, who are responsible for the future of electron spin science and technology.

The SEST Award is distributed for the first time this year to honor researchers who have made outstanding achievement in relevant fields. M. Motokawa (Tohoku Univ.) and T. Yonetani (Univ. of Pennsylvania) were honored by this award. An incentive award for young scientists started also to encourage their research. The prize winners were T. Ikoma (Tohoku Univ.), H. Hirata (Yamagata Univ.), and H. Yonemura (Kyushu Univ.).

The following new SEST board members (2004–2005) were elected at the general assembly meeting on October 30. President: H. Utsumi (Kyushu Univ.), Vice-President: S. Tero-Kubota (Tohoku Univ.), Secretary: H. Ohta (Kobe Univ.), Treasurer: T. Watanabe (Tokyo Univ. of Marine Science and Technology), Executive board members: T. Ogata (Yamagata Univ.), T. Nakamura (IMS), K. Makino (Kyoto Univ.), H. Sakurai (Kyoto Pharmaceutical Univ.), T. Ozawa (NIRS), C. Yamanaka (Osaka Univ.), H. Fujii (Sapporo Medical Univ.), H. Mino (Nagoya Univ.), M. Kuwabara (Hokkaido Univ.), T. Ichikawa (Hokkaido Univ.), K. Mukai (Ehime Univ.), J. Yamauchi (Kyoto Univ.), S. Yamauchi (Tohoku Univ.), H. Shimokawa (Kyushu Univ.), T. Yoshimura (Inst. for Life Support Technology), T. Sugawara (Univ. of Tokyo), Auditors: M. Shiotani (Hiroshima Univ.), T. Takui (Osaka City Univ.).

The upcoming annual meeting "SEST-2004" will be held in Tokyo, Japan, in fall 2004 (organizer: Dr. T. Ozawa, National Institute of Radiological Science). We give a hearty welcome to participants from abroad.

Kenji Komaguchi,
Secretary of the SEST2003

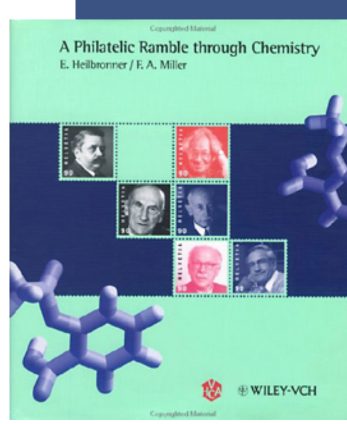
## Magnetic Resonance in Postage Stamps



**From top to bottom:**
Sweden, Nobel Prize, the 100th anniversary; USA, medical imaging; England, magnetic resonance imaging; Guyana, Felix Bloch; République de Guinée, Isidor I. Rabi; Ghana, Richard R. Ernst; St. Vincent & The Grenadines, Aleksandr M. Prokhorov; Maldives, Karl A. Müller

**For additional reading, see also:**
'A Philatelic Ramble through Chemistry' by E. Heilbronner and F. A. Miller, Wiley-VCH, 2003

**Book description:** 'A Philatelic Ramble through Chemistry' is a light-hearted historically based survey of chemistry and some related topics in physics. It is illustrated with nearly 1000 beautiful color reproductions of postage stamps and covers. Many stories and anecdotes have been included. The book provides delightful personal reading and may be useful for courses on the history of chemistry. It is a source of numerous anecdotes, which instructors can use to enliven their lectures.



For Your Perusal

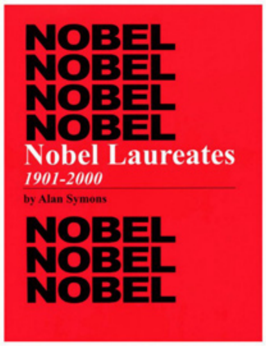
*Collected by Arthur Schweiger*

**Since this is a special issue, also this column is special. It is fully devoted to the Nobel Prize and to Nobel Laureates, but in a quite general sense. You will find books, movies, speeches and pieces of music related to the subject.**

# BOOKS

## *Nobel Laureates 1901–2000*

by Alan Symons



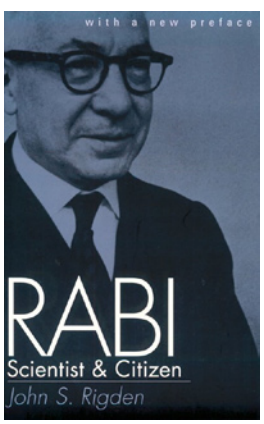

Polo Pub, May 2000, $ 34.95

This is a complete guide to the Nobel prize winners of the 20th Century. It includes 703 biographies and photographs covering all six Nobel classifications. A detailed commentary on the life and times of Alfred Nobel is given as well. A reference book with a wealth of information.

**Have a look inside this book:** eprnl.org/nobel

## *Rabi: Scientist and Citizen*

by John S. Rigden



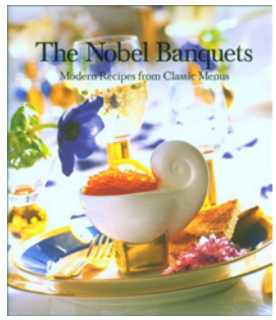

Harvard University Press, December 2001, $ 21.95

Rabi's life was remarkable, full of incident, vision and action, including war, hot and cold. The biography is a masterpiece, rich in anecdote and never losing the narrative drive. (New Scientist)

**Have a look inside this book:** eprnl.org/rabi

## *The Nobel Banquets: Modern Recipes from Classic Menus*

by Helene Bodin and Stefan Torstensson (editor)

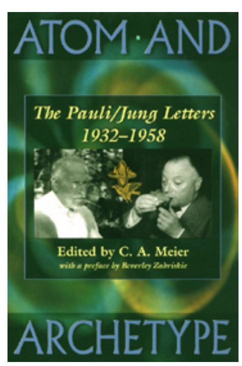



Mixoft Publishing AB, October 1998, $ 39.95

This book celebrates the history of the Banquets, and gives you a sample of the menus and recipes used, starting with the first menu from 1901. Since 1901 almost ninety Nobel dinners have been served in Stockholm on the 10th of December – the main day of the festivities. (from an editorial review)

## *Atom and Archetype: The Pauli/Jung Letters, 1932–1958*

C. A. Meier (editor) with C. P. Enz and M. Fierz



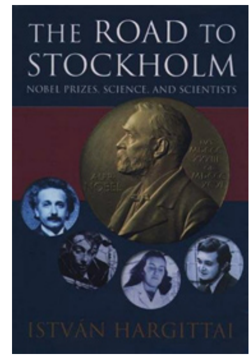

Princeton University Press, June 2001, $ 37.50

Of clear appeal to historians of science and anyone investigating the life and work of Pauli or Jung, this portrait of an incredible friendship will also draw readers interested in human creativity as well as those who merely like to be present when great minds meet. (from an editorial review)

**Have a look inside this book:** eprnl.org/atom

## *The Road to Stockholm: Nobel Prizes, Science, and Scientists*

by Istvan Hargittai and James D. Watson



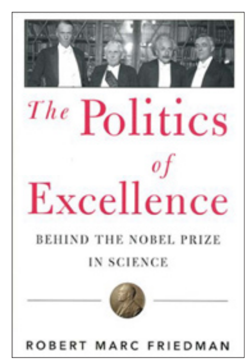

Oxford Press, May 2002, $ 29.95

This book introduces the process of selection of the laureates, discusses the ingredients for scientific discovery and for getting recognition. It also covers some discoverers and discoveries for whom and for which the Nobel Prize never materialized. (from an editorial review)

**Contents:** eprnl.org/road.pdf

## *Politics of Excellence: Behind the Nobel Prize in Science*

by Robert Marc Friedman

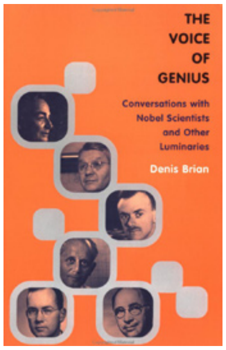



W. H. Freeman & Co., October 2001, $ 30

This idealistic study underscores the personal, scientific and cultural self-interest behind the selection of the Nobel Prizes in physics and chemistry. The author traces the prize since Alfred Nobel's enigmatic testament became public in 1897. (from an editorial review)

**Contents:** eprnl.org/politics.pdf

## *The Voice of Genius: Conversations with Nobel Scientists and Other Luminaries*
by Denis Brian

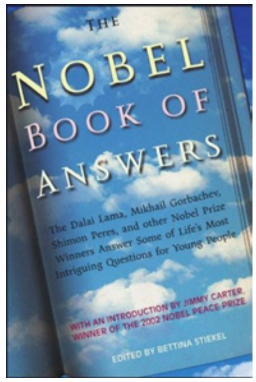



Perseus Publishing, November 2000, $ 20

Nobel Prize winners and other scientific greats reveal the secrets of the universe, human nature, and the mind. In this unique book, the author draws on some of the greatest scientific minds of the twentieth century, in pursuit of their distinct views on life, knowledge, and the cosmos. (from an editorial review)

**Have a look inside this book:** eprnl.org/genius

## *The Nobel Book of Answers*
The Dalai Lama, Mikhail Gorbachev, Shimon Peres, and other Nobel Prize Winners answer some of life's most intriguing questions for young people

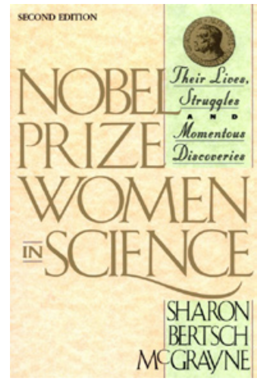



Atheneum, October 2003, $ 14.95

What if children could ask these creative thinkers about some of life's most intriguing mysteries, such as "Why can't I live on french fries?" and "What is love?" The answers are rich with surprise, humor, and of course, wisdom. (from an editorial review)

**Contents:** eprnl.org/answers.pdf

## *Nobel Prize Women in Science: Their Lives, Struggles and Momentous Discoveries*
by Sharon Bertsch McGrayne




Joseph Henry Press, February 2001, $ 19.95

Since 1901 there have been over three hundred recipients of the Nobel Prize in the sciences. Only ten of them (about 3 percent) have been women. Why? In this book, the author explores the reasons for the astonishing disparity in the number of Nobel Prizes awarded to women. (from the back cover)

**Have a look inside this book:** eprnl.org/women

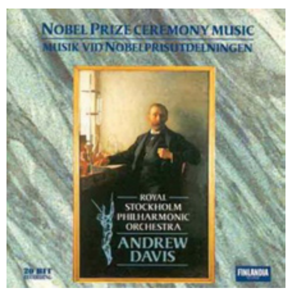
# PLAYS, SPEECHES, MOVIES, OPERAS, VIDEOS

## *Nobel Jubilee Concert (1991)*
Royal Stockholm Philharmonic
Starring: Kiri Te Kanawa,
Featuring: Georg Solti


VHS, March 1993, $ 24.95

In a concert to commemorate the Nobel Foundation's 90th anniversary as well as the 200th anniversary of Mozart's death, Sir Georg Solti conducts the Royal Stockholm Philharmonic in five arias sung by the incomparable Dame Kiri Te Kanawa.

## *Nobel Prize Ceremony Music*
Stockholm Philharmonic Orchestra,
Conductor: Sir Andrew Davis




Audio CD, Finlandia, January 1997, £ 13

On this CD you will find: Festive Music by Hugo Alfvén – Estrella de Soria by Franz Berwald – Drottningholm Music by Johan Helmich Roman – and others.

Alfven's Festive Music is apparently a regular choice and understandably so, a jolly, celebratory piece...

**Full text:** eprnl.org/music.pdf
**Extract of the Festive Music:** eprnl.org/music1.mp3

## *Einstein on the Beach*
Opera by Philip Glass (1976)

Although Einstein on the Beach is by definition an opera, Philip Glass's most famous work also transcends traditional music categories. Glass avoided all vestiges of plot in the piece and dug deep into his quiver of repetitions to create an artfully unnerving five hours of brilliance. (from an editorial review)

Illustration by Joseph Canger

**Listen to the beginning of the opera:** eprnl.org/einstein1.mp3
**Extended comment to the opera:** eprnl.org/einstein2.pdf

## *Der Meteor: Eine Komödie The Meteor: A Comedy*

by Friedrich Dürrenmatt


*"It is nice to be born as a Swiss, it is as well nice to die as a Swiss, but what you do between?"*
*Friedrich Dürrenmatt*

The Meteor (1965) is a tragicomedy about an amoral Nobel Prize winner condemned to immortality and a world populated by viciousness and greed. Dürrenmatt utilizes the dramaturgy of surprise and an array of dazzling effects in this all-out assault on Western societies. The comedy is a glittering, oblique reflection of sordid reality.

Text of the comedy in German: Diogenes Verlag, Euro 8.90; English-German version: Grove Press, $ 5.95

For one of the last photos of Friedrich Dürrenmatt, see: eprnl.org/duerr1.gif

For the painting by Varlin, see: eprnl.org/duerr4.jpg

For biographies in English, see: eprnl.org/duerr2 and eprnl.org/duerr3

## *The voice of Wolfgang Pauli*

Part of a talk given by Wolfgang Pauli at CERN in 1958 (in English)

This unique document has exclusively been made available to the readers of the *EPR newsletter*: eprnl.org/pauli.mp3

Source: Bildarchiv ETH-Bibliothek, Zürich

## *A Beautiful Mind*

Movie (2001). Starring: Russell Crowe, Ed Harris, and others


DVD, 2002, $ 30. Sound track: Audio CD, Decca U.S., December 2001, $ 19

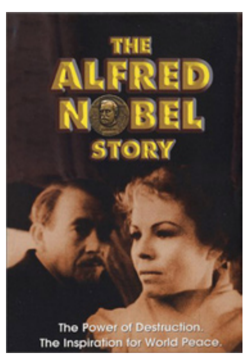
From the heights of notoriety to the depths of depravity, John Forbes Nash, Jr. experiences it all.

A mathematical genius, he made an astonishing discovery early in his career and stood on the brink of international acclaim. But Nash soon found himself on a painful and harrowing journey of self-discovery once he was diagnosed with schizophrenia. After many years of struggle, he eventually triumphed over this tragedy, and finally, in 1994, received the Nobel Prize in Economic Sciences.

**Listen to the music of the movie:**
eprnl.org/mind1.mp3 and
eprnl.org/mind2.mp3
**Have a look at a short extract:**
eprnl.org/mind3.mov
**Visit the smart website:**
eprnl.org/mind4

## *The Alfred Nobel Story*

Movie (1955). Director: Harald Braun, Starring: Werner Hinz, Matthias Wieman

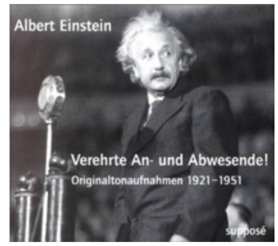



DVD, £ 8.20

This absorbing biopic tells Nobel's compelling story through the eyes of Bertha von Suttner, the first woman to win the Nobel Peace Prize.

## *Verehrte An- und Abwesende*

Audio recordings of Albert Einstein between 1921 and 1951 (partly in English)




2 Audio CD's: CD-Suppose Verlag, October 2003, EUR 24.80

For a short description (in German), see: eprnl.org/einstein6.pdf

Extract of the title talk on the occasion of the opening of the "7. Deutschen Funkausstellung und Phonoschau" in Berlin, August 22, 1930 (in German): eprnl.org/einstein3.mp3, full written text: eprnl.org/einstein4.pdf

Another extract (in German): eprnl.org/einstein5

## *The Prize (1963)*

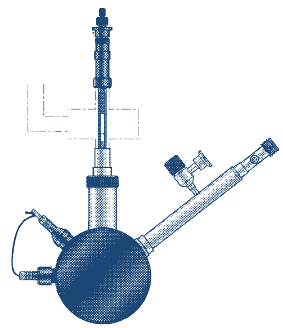
Director: Mark Robson, Starring: Paul Newman, Elke Sommer, and others


VHS, June 1992, $ 14

Andrew Craig, unlikely winner of the Nobel Prize for Literature goes to Stockholm to pick up his award and meets up with fellow scribe Dr. Max Stratman. It's a confusing but fun piece of work, buoyed up by some nice performances from Robinson, Newman and Sommer as his secretary, a nicely kitsch score, and some set pieces (check out Newman in the nudist camp) which border on parody.

**Two still photos of the movie:**
eprnl.org/prize1.pdf
**Listen to the sound track:**
eprnl.org/prize2.ram





## Positions
**Available & Wanted**

### JUNIOR NMR SPECTROSCOPIST NEEDED – U.S. ARMY MEDICAL RESEARCH INSTITUTE OF CHEMICAL DEFENSE

A junior NMR spectroscopist is needed at the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD), Aberdeen Proving Ground, MD. Position is only open to U.S. citizens. Qualified candidate must have a strong background in NMR spectroscopy.

The successful candidate will provide guidance on the operation of a Varian 600 MHz INOVA NMR and will obtain liquid and solid-state NMR spectra to aid principal investigators in studying chemical warfare (CW) agents and pharmacological countermeasures for CW agents. As NMR administrator for the Institute, the candidate will be responsible for maintaining and troubleshooting the instrument, user training, and managing the instrument in areas of biochemistry, organic, inorganic, and protein chemistry.

**Please contact:**
Dr. Carmen M. Arroyo
carmen.arroyo@amedd.army.mil
USAMRICD, 3100
Ricketts Point Rd.
APG, MD 21010
phone: 410-436-4454

### POSTDOCTORAL POSITION AT RADIATION PHYSICAL CHEMISTRY OF DNA AVAILABLE AT THE UNIVERSITY OF ROCHESTER

*University of Rochester is an Affirmative Action/Equal Opportunity Employer*

Postdoctoral Position for working on the Radiation Physical Chemistry of DNA is available at the University of Rochester Medical Center. Our research program is focused on determining the mechanisms of direct damage to DNA by ionizing radiation. Well-characterized DNA samples, in the form of films and crystals, are used to correlate free radical intermediates with stable end products. Techniques employed include EPR, GC/MS, HPLC, and gel electrophoresis. Experience in EPR, GC/MS and/or DNA chemistry is important. See my web page at dnadamage.net. The initial appointment will be for one year and is renewable. Send a complete curriculum vita, a short summary of research interests, and the names of at least three references. If possible, please use email.

**Please contact:**
William A. Bernhard
william_bernhard@urmc.rochester.edu
Department of Biochemistry & Biophysics, Box 712
University of Rochester Medical Center
Rochester, NY 14642, USA

### PRINCETON UNIVERSITY DISTINGUISHED POSTDOCTORAL FELLOWSHIPS IN EPR SPECTROSCOPY

HFSP, NIH and the Dreyfus Foundation are funding a pair of research projects at Princeton University, which supports the application of EPR spectroscopy to understanding fundamental questions in biological chemistry and materials science. Applications for a postdoctoral position are invited for an **EPR spectroscopist** with experience in pulsed EPR methods and data analysis. This person will join a team of biochemists and materials chemists in the Chemistry Department under the supervision of Charles Dismukes.

**Projects:**

- Distance Measurements in Proteins using ELDOR and Double Quantum Coherence ESR. This project aims to advance knowledge of the structure of biomolecules where XRD is not available. Applications to multi-subunit proteins, photosynthetic reaction centers and other biological materials.
- The Structure and Function of Enzymes and Inorganic Materials using Electron Nuclear Double Resonance (ENDOR) and 2D-Hyperfine Sublevel Correlation Spectroscopy (HYSCORE). To determine the electronic and magnetic environments surrounding the nuclei in coordination complexes and enzymes which determine their catalytic properties.
- Functional Dynamics of Proteins and Materials by Time Resolved FT-ESR. To study transient structural changes in photochemistry of photosynthetic reaction centers and inorganic materials related to catalysis and solar energy conversion and internal dynamics with proteins.

The postdoctoral fellow will have access to two Bruker EPR spectrometers (EleXsys 585 FT-EPR/ENDOR; ESP-300 series; ENDOR and TRIPLE accessories; fitted with Oxford helium cryostats) and major research resources in the Princeton Materials Institute and the Department of Chemistry. PhD applicants are invited with training in physics or chemistry.

Send your CV, list of publications and names and contact information for three referees who have first hand knowledge of your work to:
Ms. Lynn Mendenko
mendenko@princeton.edu
Princeton University
Hoyt Laboratory
Department of Chemistry
Princeton, NJ 08544, USA

A further description of the criteria for selection, benefits, and the project can be found at:
www.princeton.edu/siteware/administration.shtml

**Research Group links:**
Professor G. C. Dismukes
www.princeton.edu/~catalase

### POSTDOCTORAL POSITIONS AVAILABLE AT DAVIS HEART AND LUNG RESEARCH INSTITUTE, THE OHIO STATE UNIVERSITY

A position is available for a scientist with experience in magnetic resonance instrumentation development and application. The candidate should have experience in EPR/MR hardware or software development and applications to chemical or biological systems. Salary commensurate with experience. Please reference PA06 in your application.

A position is available for a scientist with experience in cardiac NMR spectroscopy or imaging research to perform isolated heart and in vivo studies of alterations in myocardial energetics and metabolism in the post-ischemic heart. Salary commensurate with experience. Please reference PA07 in your application.

The Ohio State University is an equal opportunity/affirmative action employer. Qualified women, minorities, Vietnam era veterans and individuals with disabilities are encouraged to apply.

Send CV to Dr. Jay Zweier, 473 West 12th Avenue, Room 110, Columbus, Ohio 43210 or Zweier-1@medctr.osu.edu.

# Exchange
**Equipment & Supplies**

## DO YOU NEED HELP IN DESIGN AND CONSTRUCTION OF EPR ELECTRONICS?

The University of Denver can supply electronic design and construction services for EPR applications. Low-noise pulse amplifiers, low-noise 100 kHz preamplifiers, boxcar integrators, and pulse timing systems are available.

We also supply a conversion kit to convert Varian field-control units to voltage-controlled scan operation.

A 6-digit 1-ppm frequency counter is available in X-band, C-band, S-band, L-band, or Megahertz versions.

Complete microwave/RF bridges from 150 MHz to L-band, S-band, or C-band are available from designs previously built and tested at the University of Denver.

**Please contact:**
Richard W. Quine
rquine@du.edu
phone: 1-303-871-2419

## FOR SALE: NMR MAGNETOMETER

Sentec Model 1001, including 3 standard probes covering the range of 1 to 10 kG. In good working order, this 1981 model (uses NIM bin!) includes 7-digit display, 0.01 Gauss resolution, accuracy: $10^{-6}$ relative, $10^{-5}$ absolute, has automatic peak search feature, BCD output, etc. Can be bought with or without NIM bin and CRT display. Make an offer! **Please contact:**
Prof. E. J. Knystautas
ejknyst@phy.ulaval.ca
Physics Department, University Laval
Quebec City (Quebec)
G1K 7P4
phone: 1-418-656-5569
fax: 1-418-656-2040

## FOR SALE: BRUKER EMX-200D-SRC EPR SPECTROMETER WITH ASPECT 2000 INTERFACE AND ACCESSORIES

No reasonable offer refused. Buyer will pay moving expense. **Please contact:**
Mary R. McAvoy,
Administrative Secretary
mmcavo@lsuhsc.edu
Department of Physiology
LSU Health Sciences Center
1901 Perdido St., New Orleans,
LA 70112, USA
phone: (504) 568-6172
fax: (504) 568-6158

## FOR SALE: VARIAN EQUIPMENT

Resonance Instruments has available:

1 Replacement klystrons for Varian EPR bridges (at reduced prices) and other klystrons.
2 Varian V4500-41A low/high power microwave bridge with new klystron – excellent condition.

For more information on these units **please contact:**
Clarence Arnow, President
rii1@earthlink.net
Resonance Instruments
phone: 1-847-583-1000
fax: 1-847-583-1021

## AVAILABLE: ISOTOPE-CONTAINING SPIN PROBES

A wide assortment of special $^{15}$N- and/or $^{2}$H-containing spin probes is available at moderate price. For a catalog and a price list of available compounds **please contact:**
Prof. Igor Grigor'ev
maxx@nioch.nsc.ru
Institute of Organic Chemistry
Novosibirsk 630090, Russia
In the US **please contact:**
Dr. Sergei Dikanov
dikanov@uiuc.edu

## AVAILABLE: USED VARIAN EPR EQUIPMENT

1 Varian E-104 EPR spectrometer with vertical style bridge and e-line fieldial.
2 Varian E-9 EPR spectrometer.
Both available with warranty and continued service support.
3 Varian TM cavity with flat cell holders and flat cells.
4 Varian E-257 variable temperature controller with heater sensor and insert holder.
5 Varian E-272B field/frequency lock accessory.

**Please contact:**
James Anderson,
Research Specialties
janderson36@wi.rr.com
1030 S. Main St.,
Cedar Grove, WI 53013, USA
phone/fax: 1-920-668-9905

## FOR SWAP: FAST DIGITIZERS EG&G 9825-200

We have two EG&G 9825-200 fast digitizers (EG&G instruments is now part of AMETEK Signal Recovery; the 9825 is not a current product). These 8-bit (16-bit sum) digitizers can sample up to 200 MS/s. They have a 2-board PC-AT card format. There is an external preamplifier, and software for a PC. We have replaced the EG&G digitizers with Bruker SpecJet digitizers in our saturation-recovery spectrometers, where we used the 9825 digitizers for several years. They were in good operating order when we removed them from service recently. We would be willing to swap the EG&G digitizers for something more immediately useful to us. When they were new, the list price was ca. $10K for each of the two digitizers. If you are interested, please discuss possibilities with us.

Gareth R. Eaton
geaton@du.edu


**Our quiz of *EPR newsletter* 13/4**

Fulleren is a small village in France, Alsace, Department Haut-Rhine, Sous-prefecture of Altkirch, near the Rhone-Rhine Canal. Three villages near Fulleren are Mertzen, Strueth, and St. Ulrich.

The correct answers were received from **Alessandro Ponti** (Istituto di Scienze e Tecnologie Molecolari, Milano) on June 9, 2004, and **Henryk Manikowski** (Institute of Physics, Poznań University of Technology, Poznań) on June 15, 2004.

To encourage our readership, both will get a nice postage stamp showing an endohedral fullerene where the atom inside becomes visible when warming the stamp.