First Light
The Firepower of the Idea[1]
Light at the Foundation Of Discovery

An Institution Naming Opportunity[2] for the Wisconsin Institute of Discovery[3]

A Proposal for Combed and Pumped Ultraviolet and X-Ray Laser Angle Resolved Photoemission Spectroscopy as Foundation Science for the Wisconsin Institute of Discovery – A Collaborative Effort with the Wisconsin Free Electron Laser Facility[4].

For submission with an application for reentry to the University of Wisconsin – Madison, for continuation of multidisciplinary, interdisciplinary and metadisciplinary research in the life sciences, earth sciences, space sciences and the natural sciences at UW – Madison.

For submission to the Wisconsin Institute of Discovery Theme Competition

For Joseph Bisognano - Director - Synchrotron Radiation Center[5]

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First Draft Due October 1, 2008 - Preproposal Due November 3, 2008

The Wisconsin Institute of Discovery at the University of Wisconsin, Madison, Wisconsin, is seeking scientific preproposals for five themes, directed towards the three domains of biotechnology, nanotechnology and infotechnology, ultimately addressing the need for continued future progress and improvement in providing for human health and welfare of the citizens of the State of Wisconsin, the United States of America, and the entire world.

The WID facility building architectural design lends itself to a simple proposal analysis. The building consists of five levels, which I shall call theme floors, the top three of which consist of biochemistry laboratories. Since the bulk of the proposals will undoubtedly be biochemistry proposals, we are reassured that biotechnology will be well represented.

Next is the ground level, which I label the information floor (to conserve space), used for the presentation, discussion, exchange, and dissemination of the results produced by the upper three floors, and for general public outreach and science education. Finally we have the basement level, which contains unspecified dry laboratory space, including offices and conference rooms for technology transfer into the public and private sectors.

This theme proposal is for the foundation sciences in the themes of nanotechnology and information technology, relevant to the biotechnology work being performed on the top three levels of the institution, and indeed, across the whole campus and the entire world.

The model for that foundation science is ultraviolet photolithography, which has already delivered the scientific, technological and information revolutions creating this institute in the first place, and which will unquestionably guide its future development and evolution for many years yet to come. We are all thus indebted to optical photolithography for that revolution, but we are not beholden to it. We understand the underlying disciplines are spectroscopy and condensed matter physics, and thus we are led directly to this theme, which is, upon first inspection, uniquely suitable for the Wisconsin Free Electron Laser.

Research Aims and Scope

Describe the research goals and methodologies of the theme.

The goal of this research is to secure funding for the Wisconsin Free Electron Laser.

The research methodology applied will be one of a small scale demonstration of the relevant scientific, technological, engineering and management principles of the WIFEL project development process, with a modern optical spectroscopy and ultraviolet frequency combed laser based angle resolved photoemission spectroscopy facility.

Integration of Biotechnology, Nanotechnology, and/or Information Technology

Describe how at least two of these technologies will be incorporated into the theme and will lead to scientific discovery with the potential to benefit human health and welfare.

Our current scientific revolution has come about through feature size reduction, visual display sophistication and the mass production afforded by ultraviolet photolithography. Vast increases in computing power and bulk memory space have already yielded great improvements in code generation and source archival, enabling great leaps in inquiry and abstraction. Clearly the fundamental basis for these technological and information revolutions is condensed matter physics in general, and spectroscopy in particular, which we may now call picotechnology, a necessary precursor to nanotechnology.

Condensed matter physics is clearly the nexus at which all basic science disciplines coalesce into a coherent picture of the cosmos, and from which all higher order scientific disciplines draw their basic knowledge, as they radiate outwards and intertwine into our everyday ordinary lives. Any new fundamental discoveries in condensed matter physics will send immediate and dramatic results upwards and outwards into the scientific world, through their rapid incorporation into processes and production on an industrial scale, which in turn will produce new devices and instruments by which scientific understanding progresses, technological knowledge and action are achieved – and lives are improved.

In order for this process to continue we seek the ever greater spectroscopic resolutions affordable in UV and soft X-rays by the Wisconsin Free Electron Laser facility proposal. Additionally, we intend to extend recent technological developments in compact optical excitation and near UV laser angle resolved photoemission spectroscopy, at an energy (3-10 eV) which is less than optimal for WIFEL, and much quicker and easier to achieve, on a smaller scale more appropriate for use with an expanding biotechnology user base.

New Faculty Positions

Describe the vision for the three new faculty positions, and how each will advance the theme's research and scholarly goals.

The theme research proposal asks for four tenured project managerial positions, thus restricting the vision to four fundamental scientific methods of theory and experiment, laboratory technology and project engineering and management. The model used here is the University of Wisconsin Applied Mathematics, Engineering and Physics program.[6] My particular vision is for beamline training of PhD students competent in all aspects of theoretical development, experimental investigation, and project or program engineering.

Theory and Computation

As the basis for this proposal, I present recent ab initio work which postdates the original laboratory development work, and clearly directs all future developments in this field.

http://cts.phys.ntu.edu.tw/cts/paper/SICHU/PRA08a.pdf (Paper)

Phys. Rev. A **77**, 031401(R) (2008) (Journal Reference)

Experimental Spectroscopy

As the basis for this proposal, I present the PhD thesis of Jacob D. Koralek performed at JILA - Joint Institute for Laboratory Astrophysics at the University of Colorado in Boulder.

http://jilawww.colorado.edu/pubs/thesis/koralek/ (Sections)
http://jilawww.colorado.edu/pubs/thesis/koralek/koralek_thesis.pdf (Full Thesis)

To clearly demonstrate the rapidity and international ramifications of some developments in this new field, I present a clear challenge by Chinese researchers to excel in this area.

http://arxiv.org/abs/0711.0282 (Abstract)
http://arxiv.org/pdf/0711.0282v1 (Paper)

Rev. Sci. Instrum. **79**, 023105 (2008) (Journal Reference)

This newly commissioned facility produced a set of first results, which were posted on the first day of the Beijing Olympics, which again sets the bar for future developments.

http://arxiv.org/abs/0808.0806 (Abstract)
http://arxiv.org/abs/0808.0802 (Abstract)

Laser Laboratory Technology

As the basis for this proposal I present recent laser laboratory technology work, which clearly sets the bar for future developments in the field of optical and UV spectroscopy.

http://arxiv.org/abs/0803.4509 (Abstract)
http://arxiv.org/pdf/0803.4509v1 (Paper)

Appl. Phys. B **91**, 397-414 (2008) (Journal Reference)

Program and Project Engineering

As a mere consumer of photoemission results and products, i.e. - scientific publications, I had been unaware of recent developments in the field of VUV and X-ray spectroscopy.

I present the original National Science Foundation facility proposal for the Wisconsin Free Electron Laser (WIFEL) at the University of Wisconsin in Madison, Wisconsin.

http://www.wifel.wisc.edu/WiFEL_R&D_Proposal.pdf (Proposal)
http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/TUPMS041.PDF (Paper)

Collaboration and Interdisciplinary Activities

Describe plans for interaction and collaboration among faculty members that comprise the theme and with others on campus, and identify the range of disciplines involved.

All program and project management operations may be broken down into fundamental mathematical, scientific, technological and engineering components and constituents. In order to successfully identify and navigate any unknowns, which are bound to occur in the problem solving processes at the heart of discovery, the efforts in any one of these areas may be further modeled after the analogous scientific methods themselves. In the case of mathematics, this is creativity in theory and computational expertise. In the case of science, that is empirical and experimental demonstration. In the case of technology, it is the design of the instruments and the laboratories of investigation, and in the case of engineering, it is construction of the facilities and successful completion of the project.

In the case of many big science programs like the LHC, the project is so complex and expensive that large international partnerships and collaborations are required. In the case of medium science national programs, many institutional and university teams may be assembled. In the case of a small floor level project such as this, the challenge here is to successfully execute the project with only four leads. But the same model is valid.

In order to demonstrate how this model operates, I shall use examples from the scientific breakthrough a day paradigm we now enjoy with modern UV and X-ray spectroscopies.

Theory and Computation

My clear intent here is to bring the mathematics department under the WID umbrella, but perhaps it is appropriate that it towers over the proceedings, exceeded in stature only by the UW administration offices and the state capitol. Philosophy and politics aside, one is confronted with an astonishing set of codes, tools, machinery and resources with which to approach an exact requirement of data extraction, (de)convolution and representation, in order for high level analysis and abstraction to occur, such that discovery is inevitable.

At the highest level of abstraction, it is fundamental papers, like this research proposal, dealing with questions like what can we do, what do we want to do, and why do we want to do it. At the lowest level of implementation it is the programming, coding and archiving of our combined evolutionary skill, with nearly instant access to the totality of knowledge.

On the computational side, recent advances in multi core processors, object oriented languages, open source archive, and 3D mesh manipulation with physics simulation, have clearly outlined many obvious directions to proceed in terms of collaboration.

Experimental Spectroscopy

A synthesis of understanding occurs among consumers of spectroscopy publications. On any weekday evening one can get onto the archive and download the day's papers. For instance, twenty years after the discovery of the high temperature superconductors, a glimmer of understanding is just beginning to occur. Recent discovery of a new class of high temperature superconductors initiated a flurry of activity, which closed the loop between experimental spectroscopy and the band and electronic structure calculations. From a condensed matter physics view, stunning revelations are occurring day by day.

As an example, a certain Nobel laureate recently published a paper, which sets a tone :

http://arxiv.org/abs/0809.2881 – *Polaron Coherence as Origin of the Pseudogap Phase.*

Here the relevant spectroscopy was EXAFS, collected at a synchrotron radiation facility. A result such as this still remains at the very edge of experimental resolution, but with increased resolution, one can begin to ask why it is we are pursuing exotic phenomena :

http://arxiv.org/abs/0809.2272 – Melting at the absolute zero of temperature: Quantum phase transitions in condensed matter. This is a great example of high level abstraction, as a threshold of understanding is reached within the cumulative results of spectroscopy.

This field will continue to push chemical physics and quantum chemistry to their limits, as a threshold of resolution continues to shrink, enabled by UV and X-ray spectroscopy.

Laser Laboratory Technology

Here I am at a great disadvantage, because these are the skill sets I have chosen to develop with this research project. I estimate at least two years just to come up to speed, just about the time the facility is finished and the staff is moving in – hence this proposal.

A proposal of this nature demands broad collaborations across all hard science fields, but it is expected that the engineering and physics departments will be the focus here. The consumers of services will be biotechnologists on the upper levels of the institution. Insights into their motivations and desires are a necessary component of the instrument design process, as they represent the wishes of the founders and the stakeholders, and with respect to human health and welfare, citizens of Wisconsin, the US and the world.

Program and Project Engineering

The engineering lead operates at the program and project management, administrative and executive director levels, and thus must be competent in all aspects of the system. As such one expects networking across all boundaries – institutional, university, national and international, fluency in mathematics, engineering, science and technology, and as is often the case for modern science, understanding of political and social expediencies. My personal further divisions of science are the natural sciences, space sciences, earth sciences and life sciences, embodied by mathematics, physics, chemistry and biology. Once a broad foundation in the hard sciences is provided, discoveries naturally follow.

Innovation and Fit

Describe how the theme is innovative and creative, and why it is a good fit for WID.

This theme isn't particularly innovative or creative. It was arrived at by simple logical deduction based upon first principles analysis of existing and necessary infrastructure. Creativity and innovation will be what the biotechnologists and facility users engage in. On the other hand, this proposal is very nearly a perfect fit for the Institute of Discovery, and one can only imagine this is precisely what the founders had in mind when starting. Whether fortuitous or not, a new exploratory institute based upon a solid foundation of mathematical, scientific, technological and engineering principles simply cannot fail – principles which are ideally and uniquely provided by the Wisconsin Free Electron Laser.

What is the potential impact on interdisciplinary research and education at UW–Madison.

The scientific impact of the Wisconsin Free Electron Laser in particular, and ab initio and first principles theoretical analysis coupled with nearly real time optical, ultraviolet and soft x-ray spectroscopy in general, has been immense, widespread and nearly universal. Condensed matter physics, unsung hero and best kept secret of the physical sciences, invisibly infiltrates every aspect of your ordinary and mundane existence of things that you can hold in your hand. It is important to remind people every day of the gratitude that we all owe to this field, and the best way to do that is with a science breakthrough a day, which is very nearly what the existing synchrotron radiation centers are producing now. Incredible improvements are expected given real time feedback effects we already see.

What we expect to do with the WIFEL is to train and unleash into the broader scientific community the best interdisciplinary research scientists in the world, as well as making the UW-Madison the de facto world class standard in project engineering management.

Faculty Theme Leader

Describe track record and capacity of the lead faculty member to serve as theme leader.

Joseph Bisognano is the Director of the Synchrotron Radiation Center and is the (admittedly alphabetical) lead author of the Wisconsin Free Electron Laser proposal.

Names and departmental affiliations of faculty who will serve as the theme Advisory Committee and who will be part of the larger theme activities on campus.

Robert Joynt – Physics
Lawrence Dahl – Chemistry
Joseph Bisognano – Engineering

References

1. Marsha Mailick Seltzer – Interim Director – First Theme Meeting
2. John D. Wiley – Interim Director – Third Theme Meeting

3. WID – Wisconsin Institute of Discovery

http://www.discovery.wisc.edu/
http://www.wid.wisc.edu/

4. WIFEL – Wisconsin Free Electron Laser

http://www.wifel.wisc.edu/index.htm

5. SRC – Synchrotron Radiation Center

http://www.src.wisc.edu/index.htm

6. UW – University of Wisconsin – Applied Mathematics, Engineering and Physics

http://www.wisc.edu/pubs/ug/10lettsci/depts/amep.html