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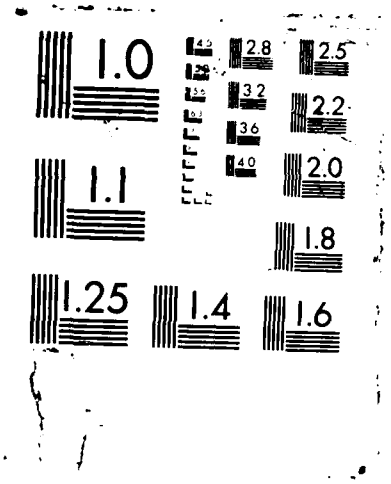
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Samuel D. Bader and Gopal K. Shenoy

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A soft x-ray undulator is to be based at the vacuum ultra-violet storage ring at the National Synchrotron Light Source. The undulator will be used as a radiation source by a multi-institutional research team to perform the first spin-polarized photoemission experiments in the United States to study novel ultra-thin magnetic films and surfaces.

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Annual Report:

December 1986 - December 1987

SOFT-X-RAY UNDULATOR

S. D. Bader

Materials Science Division

Argonne National Laboratory

Argonne, Illinois 60439

Office of Naval Research Contract #N00014-87-F-0022

FEL Applications Program

Strategic Defense Initiative Program Funding

This is the first annual report for a two-year program to base a soft x-ray undulator at the vacuum ultra-violet (VUV) storage ring at the National Synchrotron Light Source (NSLS). The undulator will be used as a radiation source by multi-institutional research teams to perform the first spin-polarized photoemission experiments in the United States. The undulator source will permit major advances to take place in materials research in the forefront area of novel, ultra-thin magnetic films and surfaces.

The activities are summarized on the attached bulletized "Chronology of Activities". Contractual arrangements with ONR were successfully completed and the undulator procurement process was initiated. Technical specifications and evaluation criteria were finalized. A synopsis to invite bidders appeared in the Commerce Business Daily (see attached). Bids were received and recommendations were made by a Technical Evaluation Team to the Argonne Source Selection Board. A purchase order will be placed in a timely fashion as internal and DOE reviews are completed.

Two auxiliary equipment issues are being pursued simultaneously. One invokes the vacuum chamber assembly that the undulator envelopes. A bid has been received for a ribbed chamber that accommodates the pole corrugations of the undulator. The other involves photon beam monitoring and feedback control for beam positional stability. Various strategies for ensuring stability have been evaluated and the task has been divided into two parts. First data will be collected with a passive monitoring system to evaluate (i) the magnitude and (ii) the frequency spectrum of the instability, and (iii) the passive measures that can be taken to minimize instabilities. Then an appropriate feedback system will be instituted as needed. These auxiliary issues involve open and continuing dialogue with NSLS staff personnel.

Related programmatic activities included: a) invited talks at major national/international meetings on "Magnetic Properties of Novel Epitaxial Films", and b) numerous publications on the subject, including invited papers and letters. Synchrotron-radiation-related activities included: a) a tour of the Photon Factory in Tsukuba, Japan, b) participation in the SRI Conference, Madison, Wisconsin, c) participation in magnetic x-ray scattering experiments at the Cornell High-Energy Synchrotron Source (CHESS), and d) appointment to the Program Committee of the upcoming conference (sponsored by NSLS and the American Vacuum Society) entitled "Vacuum Design of Advanced and Compact Synchrotron Light Sources".

Enclosed also is an invited summary for the forthcoming meeting on "FEL Applications in the Ultraviolet" sponsored by the Optical Society of America. It is entitled "Novel Magnetic Materials Research Using Free Electron Lasers". It contains a comparison of the estimated source flux from the soft-x-ray undulator of the present proposal to that anticipated from the conceptual design for futuristic FEL sources.

Chronology of Activities

December 15, 1986	• Start date of Contract.
February 1987	• Contract Reviewed at ONR for Fiscal Data.
	• Department of Energy accepts $1,017,583 incremental funding.
March 1987	• Argonne Account 8C437-00 set up.
	• Iterate specifications with NSLS Machine physicists.
April 1987	• Undulator procurement process starts at ANL.
	• Tour Photon Factory, Tsukuba, Japan.*
May 1987	• ONR Contractors Meeting for SDIO/FEL Programs.
	• Commerce Business Daily Synopsis Appears.
June 1987	• Synchrotron Radiation Instrumentation Conference, Madison, Wisconsin.*
July 1987	• DOE accepts $366,417 incremental funding.
August-September 1987	• Proposals received from bidders.
	• Appointment to Program Committee: "Vacuum Design of Advanced and Compact-Synchrotron Light Sources", NSLS/AVS.*
October 1987	• Technical Evaluation Team forwards Recommendations to ANL Procurement.
	• Summary prepared for Optical Society of America Topical Meeting on FEL Applications in the Ultraviolet".*
November 1987	• DOE accepts $198,000 final funding increment.
December 1987	• Magnetic X-ray Scattering Experiments at CHESS, Cornell University.*

*Related (not supported).

ARGONNE
NATIONAL
LABORATORY

INTRA-LABORATORY MEMO

May 15, 1987

TO: DonCarlos James PRO/201

FROM: S. D. Bader MSD/223 SDB

RE: CBD Synopsis

Specification for a Hybrid Undulator for the U5 Beamline at NSLS

This specification is for the design and fabrication of the basic magnetic and mechanical structure of a permanent-magnet hybrid undulator to be used on the U5 beamline on the vacuum ultraviolet VUV ring at National Synchrotron Light Source (NSLS). The device shall have a variable gap with provisions for remote adjustments incorporated into the design. The first choice for the permanent magnet materials shall be the Nd-Fe-B alloy and for the ferromagnetic pole, vanadium permendur. The specifications are such that the undulator will provide the recommended field strength and the smallest bandwidth on the first and third harmonic radiation within the emittance of VUV ring. Both the magnetic and mechanical properties are to be compatible with the vacuum chamber housing of the storage ring. The stand and mechanical structure shall also comply with the space requirements of the storage ring. End correctors, end-field clamps, and residual steering errors shall comply with the NSLS requirements for the VUV ring.

The permanent magnet materials shall have a minimum coercive force of 10.6 kOe. The recommended period is 7.5 cm and the maximum length is 2.25 m. The gap adjustment should be rugged and dependable for constant daily operation from a minimum of 2.4 cm to a maximum such that the on-axis magnetic field is less than 500 Gauss. The gap setting shall be reproducible to within 0.001 inch. The maximum deviation of the midplane field variation from a pure sinusoidal one shall be less than 2% at any gap setting to within 2 period on each end of the device. The device shall be delivered to NSLS within fifteen months from the acceptance of the order.

SDB/b

Commerce Business Daily

WEDNESDAY, May 27, 1987

Issue No. PSA-9347

A daily list of U.S. Government procurement invitations, contract awards, subcontracting leads, sales of surplus property and foreign business opportunities

PROCUREMENT

MAY 27 '87

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U.S. GOVERNMENT PROCUREMENTS

Services

A Experimental, Developmental, Test and Research Work (research includes both basic and applied research)

Argonne Nat'l Lab, Procurement Dept, 9700 South Cass Ave, Argonne, IL 60439-4873

A – SPECIFICATION FOR A HYBRID UNDULATOR FUR THE US BEAMLINE AT NSLS This specification is for the design and fabrication of the basic magnetic and mechanical structure of a permanent-magnet hybrid undulator to be used on the US beamline on the vacuum ultraviolet VUV ring at Nat'l Synchrotron Light Source (NSLS). The device shall have a variable gap with provisions for remote adjustments incorporated into the design. The first choice for the permanent magnet mat'ls shall be the Nd-Fe-B alloy and for the ferromagnetic pole, vanadium permendur. The specs are such that the undulator will provide the recommended field strength and the smallest bandwidth on the first and third harmonic radiation within the emittance of VUV ring. The permanent magnet mat'ls shall have a minimum coercive force of 10 6 kOe. The recommended period is 7.5 cm and the maximum length is 2.25 m. The gap adjustment should be rugged and dependable for constant daily operation from a minimum of 2.4 cm to a maximum such that the on-axis magnetic field is less that 500 Gauss. The gap setting shall be reproducible to within 0.001 inch. The maximum deviation of the midplane field variation from a pure sinusoidal one shall be less than 2% at any gap setting to within 2 period on each end of the device. The device shall be delivered to NSLS within fifteen months from the acceptance of the order. The purpose of this announcement is to establish a bidders list. Interested organizations will be placed on the bidders list by requesting in writing. Attn Don Carlos James, Bldg 201-PRO. This announcement closes 15 days after publication of this notice. (141)

US Army Belvoir Research, Development and Eng Ctr, Belvoir Procurement Div, Ft Belvoir, VA 22060-5606

A – IMPROVED CLARIFICATION SYS Sol DAAK70-87-R-0117. 7/7/87, 8/10/87 response date. Contact K Sterne, Contr Specialist, Attn AMSTR-PBLL, 703/664-5148. Contr Officer, Robert Tobey. Configuration objective less than 4000 lbs of wt, fit within 4' x 5' x 4' high envelope, or provide info as to how sys could be redesigned to meet the space/wt objectives. Qty 1 sys. Performance specs include: 1. Capable of producing 50 gals per minute (GPM) feedwater, with a turbidity of less than one nephelometric turbidity unit (1 NTU) from raw water source ranging in turbidity from 0 to 150 NTUs. If the sys cannot produce an effluent water of less than 1 NTU, the offeror must identify what add'l treatment steps would be necessary to achieve this performance. 2. Sys should not use any consumable mat'ls that would have to be replaced during the course of water production. 3. The equip will be constructed of mat'ls that will allow sys to operate on water with a total dissolved solids (TDS) concentration range from 0 to 40,000 milligrams per liter. This range covers water commonly referred to as fresh, brackish, and seawater. 4. Sys will be supplied with (i) all manuals necessary for sys operation and maintenance, (ii) all mat'ls required for maintenance and repairs expected within a 2000 hr operational cycle, (iii) level I drawings, MIL-DTL-7031, (iv) 20 hrs of on-site support prior to the start of Govt testing. FOB destination Ft Belvoir Research, Development and Engr Ctr, Ft Belvoir, VA. Del: 90 days after contract award. Reqs for sol may be made by letter or telegram. All resp sources may submit a proposal which will be considered. The Govt reserves the right to make more than 1 award. (142)

National Institutes of Health ... [illegible] ... Pike, ... OF ... 2501 ...

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INFO Don Carlos James.
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... 2) headlight system illumination that should be directed to different locations so that drivers can safely and comfortably tolerate glare from oncoming and following vehicles and 3) other safety relevant driver visual needs that can be identified. The procurement requires the creation of a computer program to evaluate the degree to which a headlight system meets the criteria developed. The period of performance is for eighteen months. RFP will be mailed only to organizations who submit written requests to this announcement. Requests must include two self-addressed mailing labels citing the RFP NUMBER. Anticipated issue date is 06-15-87. Note 80 applies. Note 64 applies except that the sol. will be furnished to any interested party furnishing a written request and two self-addressed labels. (142)

Dept of Transportation, National Hwy Traffic Safety Administration, Office of Contrs and Procurement, NAD-30, 400 Seventh St, SW, Rm 5301, Washington, DC 20590

A – SIDE WINDOW EJECTION REDUCTION STUDY sol DTNH22-87-R-07442. BOD: Jul 15 87. POC Alberta Jones, contr specialist, 202/366-9566. This procurement is to carry out the engineering design of the required strengths of the T-edges and channels, build side doors with the design using standard automotive construction techniques, and test the moveable attached-plastic glass-plastic design. The tests include the following: (1) drop tests with spherical weights and dummies, (2) sled tests with dummies and (3) one side impact car crash test with a dummy. The goal of this project is to demonstrate a practical automotive design for moveable side window ejection reduction by attached. Plastic glass. Plastic glazing. This sol is being mailed to those organizations responding in writing to this announcement along with two pre-addressed mailing labels. Anticipated issue date is Jun 15 87. Note 80 applies. Note 64 applies except that the sol will be furnished to any interested part furnishing a written request and two self-addressed labels. (142)

Commander, Naval Ocean Systems Center, San Diego, CA 92152-5000: Attn: Code 216

A – DEVELOP INTEGRATED CIRCUIT A/D CONVERTER WITH ANTI-ALIAS FILTER N66001-87-R-0324. Closing date o/a 07-15-87. Joyce Cerna, 619/225-6758/6462. For copies of sols notice: Only written requests will be honored. Anita Dale Negotiator. Julie Brooke Contracting Officer. Develop an ultra-low power charge-mode integrated circuit A/D converter with anti-alias filter. Effort involves development of initial design modules (multichip-1), process development using multichip-1, and the evaluation of initial design modules on multichip-1. CPFF, twelve month effort contemplated. Sol to be issued o/a 06-15-87. See Note 22.

A – DIGITAL FILTER INTEGRATED CIRCUIT N66001-87-R-0325. Closing date o/a 07-15-87. Joyce Cerna, 619/225-6758/6462. For copies of sols, notice: Only written requests will be honored. Anita Dale Negotiator. Julie Brooke Contracting Officer. Develop an ultra low power linear phase digital filter integrated circuit. Effort will involve development, analysis, design and simulation. A twelve month effort is contemplated, using a CPFF contract. Sol to be issued o/a 06-15-87. (142)

Headquarters Contrs Branch, Div of Contrs & Grants Management, HFA-512, 5600 Fishers Lane, Park Building, Rm 3-30, Rockville, MD 20857

A – ESTABLISHMENT OF METHODOLOGIES TO ASSESS DIFFERENCES IN COMPLICATION RATES FOR SELECTED PROSTHETIC MECHANICAL HEART VALVES Sol 223-87-6003. BOD: 6/30/87. Contact, Patrice Caldwell, 301/443-4420. Contr Officer, Cynthia A Howley, 301/443-4460. The objective of the contr is to identify and develop methodologies which can best examine possible differences in valve thrombosis, thromboembolism, and other adverse events among patients receiving different generic classes of prosthetic mechanical heart valve implants. Once the methodologies are evaluated and determined feasible, then perform a pilot study for one or more of these methodologies. This phase of the study will be performed in at least 2 clinical centers and must include an appropriate No. of patients. (141)

NASA-Ames Research Center, Mail Stop 241-1, Moffett Field, CA 94035.

A – DESIGN, FABRICATION AND TESTING OF THROTTLE AND NOZZLE SERVOS AND SERVE CONTROL UNIT RFP2-33018(CJD) due 07-26-87. POC: Carole Davis, 415/694-5786; Ava N. Johnson, 415/694-5786. Throttle and nozzle servos and a servo control unit for V/STOL research airplane. This equipment will be installed in the YAV-8B which is being used as a V/STOL research airplane at NASA Ames Research Center, Moffett Field, CA an additional throttle parallel servo and an additional nozzel parallel servo will be installed in an Integration and Test Facility (ITF) which will be used to develop and test flight hardware and software. Each of two Servo Control Units (SCU) will provide the capability to drive five existing attitude control servos, two attitude trim servos, the series and parallel throttle servos and the series and parallel nozzle servos. All responsible sources may submit a proposal which shall be considered by the agency. (142)

H Expert and Consultant Services

Nat'l Institute of Mental Health, Contrs Management Branch, ORM, Parklawn Bldg, Rm 15-81, 5600 Fishers Lane, Rockville MD 20857, Attn: Mary E. Bilstad, Contr Specialist, 301/443-2696

H – MENTAL HEALTH POLICY RESOURCE CENTER NIMH-PA-87-0026. POC David J. Estenaza, 301/443-2696. The purpose of this effort is to pilot test for 3 years (to be funded incrementally subject to satisfactory performance availability of funds) the establishment of a Nat'l Mental Health Policy Center which will be responsive to the needs of federal, state and local communities for significant mental health policy info. The objectives are to: (1) provide an objective, central source of info and other resources to analyze and develop options for policies in the mental health field for utilization by research/academic communities, nat'l mental health organizations, and state, local and federal govt agencies, (2) collect, analyze, process and exchange info to support mental

Content

NOVEL MAGNETIC MATERIALS RESEARCH USING FREE ELECTRON LASERS*

S. D. Bader

Materials Science Division

Argonne National Laboratory, Argonne, Illinois 60439

October 1987

jmg

INVITED paper submitted to Optical Society of America Topical Meeting on Free-Electron Laser Applications in the Ultraviolet, Cloudcroft, New Mexico, March 2-5, 1988.

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*Work supported by the U.S. Department of Energy, BES-Materials Sciences, under Contract #W-31-109-ENG-38.

Novel Magnetic Materials Research Using Free Electron Lasers

S. D. Bader
Materials Science Division
Argonne National Laboratory
Argonne, IL 60439

Synchrotron-radiation sources have dramatically increased the research capabilities of materials scientists. This increase has motivated advances in source development, from the

(i) early, "parasitic" stage, to the
(ii) present- day, dedicated bending-magnet stage, to the
(iii) proposed, all-insertion-device stage.

This latter development will permit spin-polarized photoelectron spectroscopy to become a convenient probe of magnetic materials. This form of spectroscopy warrants undulator radiation sources because electron spin detectors are inefficient by a factor of 10^{-4} compared to conventional photoelectron detection.[1] Thus, it becomes very exciting to consider the future scientific possibilities offered in the ultimate stage in the source progression: the realization of soft x-ray free electron lasers (FEL). In the following, broad examples of magnetic materials research opportunities are considered. Order-of-magnitude estimates are then given of source flux and spin-polarized signal level for an undulator and an FEL source. The comparision illustrates the impact expected of FEL sources on magnetic materials research in the future.

The classes of physical phenomena that can benefit from spin-polarized photoemission studies are diverse and include

(i) the characterization of ground-state magnetic properties, and the challenge of testing local-density-theory predictions,[2]
(ii) the area of surface magnetic critical phenomena,[3] and
(iii) the photo-excitation process itself, by adding the spin dimension to screening and resonant mechanistic studies.

The area of surface-modified magnetic order includes the characterization of

(i) magnetic dead layers,
(ii) enhanced magnetic moments at the surface, and even
(iii) new types of magnetic order.

Model systems involve

(i) surfaces of bulk materials,
(ii) epitaxial ferromagnetic mono-, bi- and tri-layers, etc., and even

(iii) one-dimensional magnetic chains, such as might be realized by lithographic techniques or by selectively adsorbing magnetic adatoms at ordered step sites of non-magnetic substrates.

The theoretical description of finite-temperature magnetism, and the role of short-range order and spin fluctuations presents an open challenge. The interplay of magnetism and

(i) chemisorption,
(ii) surface segregation, [4]
(iii) surface order-disorder phenomena,[5] and
(iv) epitaxy and film growth, [6] etc.

provide numerous problems requiring additional experimental elucidation. The method of epitaxial growth enables one to "atomically engineer" magnetic properties of interest by altering natural lattice constants, and by stabilizing unstable and new phases of bulk materials.[7]

The area of f-electron magnetism provides localized magnetic order in rare-earth metals, in contrast to the itinerant magnetism of transition metals, and the challenges of "heavy-fermion" behavior in certain cerium-, uranium-, and transuranic-based materials. Rare-earth materials often exhibit helical magnetic structures. Creating these materials in ultrathin form via epitaxy necessarily should induce new properties because the film thickness can be engineered to be less than the pitch of the helix. In the heavy-fermion systems the measurement of the width of the electronic structural features in the vicinity of the Fermi level is believed to be resolution limited at present.

The question of the nature of the amorphous state has benefitted recently from a deeper understanding of the structure of disordered materials. Magnetic-glass research poses the interesting possibility of assessing the role of magnetism in helping to stabilize the amorphous state. This is an area that is also at the interface of basic and applied research because of the technological applications of magnetic glasses. Other technological materials include magnetic recording media[8] and magnetic catalysts[9]. It is known, for example, that chemical reaction rates can differ in character above and below the magnetic ordering temperature of the catalyst.

Magneto-optical materials are important in the future development of magnetic information technologies. Magneto-optical properties in the soft x-ray range have not been explored.[10] Transition-metal-rare-earth systems should show interesting reversals of the magneto-optic coupling strength as the photon energy is increased. There is also great interest here in increasing the photon energy to core-level threshhold energies. Non-linear magneto-optic effects and second-harmonic generation further contribute to the richness of opportunities. These studies can be pursued simultaneously with photoemission experiments.

Spin-polarized photoemission of dilute magnetic alloys potentially could provide a clear illustration of the fundemental interactions that lead to magnetic order. Even exotic host materials could be utilized, such as superconducting materials. Ternary superconductors and the new high-T_c oxide superconductors can tolerate a magnetic atom in each unit cell of the material. There is very little understanding of the influence of superconductivity on magnetic ordering. Usually the approach is applied in reverse, and the influence of magnetism in suppressing superconductivity is studied. Dilute magnetic systems could be created artificially, as well, via optical pumping techniques. This presumably could be done in much the same way as the molecular photophysicists and semiconductor researchers envision pump-probe experiments.

Having enumerated a variety of interesting topics in magnetic materials research, it is of interest to evaluate technical considerations to determine the appropriate source for a given experiment. For the undulator source the estimate presented below is based on a device on the VUV storage ring at the National Synchrotron Light Source (NSLS). This undulator is chosen because it is planned for installation at a beamline dedicated to spin-polarized photoemission. It is a hybrid, over 2 m long, with a period of 7.5 cm. It will be constructed of neodymium-iron-based permanent magnets and vanadium permendur poles. The FEL source used in the comparison is that conceptually designed at Los Alamos National Laboratory for operation on an rf linac. The comparison is made at 50 eV, which is a high photon energy for angle-resolved experiments. The rf-linac FEL flux drops approximately as the square of photon energy as photon energy increases in this range, so it is a conservative estimate of FEL performance when extended to lower energies. The undulator has a usable source flux of 4×10^{14} photons/sec/0.1% bandwidth. This is for an on-axis pinhole collection angle (0.2 mrad x 0.2 mrad) that includes the natural opening angle of the radiation. The rf-linac FEL provides a factor of 10^3 increase in flux over that of the undulator, with the bandwidth measured in cm^{-1} units! The count rate at the spin detector from an iron sample is expected to be in the kHz and MHz range, respectively, for the undulator and FEL source. This takes into account the photoemission cross section and the spin detector efficiency. An additional consideration is that the undulator source requires a monochromator, while the FEL would not. Transmission loses in the monochromator are difficult to factor in, but they will be present. The comparison illustrates striking advantages of the FEL source. The flux is orders of magnitude improved over that of the undulator. The FEL source collimation and spectral and polarization purity are all improved over that of the undulator as well.

For spin-polarized photoemission studies the advance from the undulator to the FEL source is a development that parallels that which is occurring in conventional photoemission studies in going from bending-magnet sources to undulators. This latter advance has captured the imagination of the scientific community and motivated major advanced-source projects world-wide. The scientific case in support of such projects documents the need for undulator

radiation. The following materials research areas have, thus, been identified:

(i) pump and probe experiments,
(ii) dilute impurity studies,
(iii) relaxation phenomenon, and
(iv) photoelectron microscopy.

It is important to note that the spin-polarized analogue of each of these generic areas would require FEL sources to be comparably successful. Another critical point is that the areas of magnetic materials research that are already accessible with undulator radiation would be significantly improved by the availability of FEL sources. The improvements could qualitatively change the importance of the experiment. For instance, it would be interesting if the enhanced monochromaticity of the FEL source would reveal magnon sidebands on the photoelectron spectra.

While many of the areas considered above take advantage of photon-energy tunability and enhanced flux, the photoelectron microscope would directly benefit as well from the superior brilliance of the FEL source. The ability to focus the radiation within a magnetic domain eliminates the technical problem of magnetizing the sample. This is a non-trivial issue, since stray magnetic fields can deflect photoelectron trajectories in undesirable ways.

In addition, FEL sources provide the potential for opening up new scientific frontiers based on ideas that have yet to be conceived. Given the intellectual challenges these sources provide, such frontiers are expected to be encountered, and their exploration will undoubtedly be richly rewarding.

This work was supported by the U. S. Department of Energy, BES-Materials Sciences, under Contract No. W-31-109-ENG-38. The undulator development project at NSLS is supported by the ONR under Contract No. N00014-87-F-0022.

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N00014-87-F-0022

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