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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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March 1989 - February 1990

SOFT X-RAY UNDULATOR

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Materials Science Division
Argonne National Laboratory
Argonne, Illinois 60439

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

MFEL Program

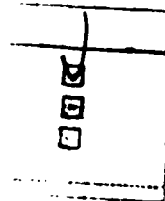
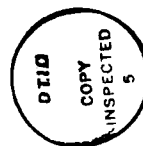
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This is the third annual report for a two-year program to base a soft x-ray undulator at the vacuum ultra-violet (VUV) storage ring at the National Synchrotron Light Source (NSLS). The undulator will be used as a radiation source by multi-institutional research teams to perform pioneering spin-polarized photoemission experiments. The undulator source will provide major opportunities in materials research in the forefront area of ultrathin magnetic films and surfaces.

The most important achievements of the past year are that construction has proceeded on the undulator and on the vacuum chamber that the undulator encases. The undulator fabrication is completed and advanced magnetic measurements are presently underway at Spectra Technology, Inc. (STI), an Amoco Company, located in Bellevue, Washington. Monthly progress reports submitted by STI are appended to this report. The undulator installation on the NSLS VUV ring was to take place during the February, 1990 shutdown of the ring. That shutdown has been postponed to the two-week period that begins on April 23, 1990. According to the original timetable the undulator would have been delivered to NSLS in January, 1990, but given the delay at NSLS it seemed wise to use the extra time to make advanced magnetic measurements. The measurements indicate that we have a state-of-the-art device. No difficulties are anticipated in meeting the new installation schedule.

The vacuum chamber is being fabricated at NSLS. Completion of fabrication has been promised by thirty days before the ring shutdown. Efforts at Argonne presently concern four issues: (i) coordination of the installation of the new undulator and vacuum chamber; (ii) evaluation of the magnetic-field characterization of the new undulator; (iii) design of methodology to test the undulator performance via the radiation it produces; and (iv) evaluation of the heat load on the near front-end components. This latter effort was somewhat unanticipated because NSLS already has a front-end installed on the beamline. But it may be substandard for our applications at high K-values and require upgrading.



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For this reason and due to the delay in the scheduled shutdown at NSLS, a no-funds extension of the existing contract with ONR is being sought for a one-year period.

Two figures are appended to this report. One is a schematic of the undulator that was produced during the design phase of the project. The other is a color photo of the actual device mounted on a dolly with a field-measurement track in the foreground.

As a result of participation in the SDIO/MFEL Program the principle investigator was asked by the American Vacuum Society to organize an International Conference on the Vacuum Design of Advanced Synchrotron Light Sources. That meeting will be held at Argonne National Laboratory on November 13-15, 1990. Every effort will be made to welcome the participation of researchers working on the new free-electron-laser source projects.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

16 February 1989 - 15 March 1989

The detailed design for the undulator has been completed for approval with the final design review. The end correctors were completely designed and detailed as well. Information from BNL was finally received concerning the action items agreed upon at the preliminary design review. Attention must be given that lack of information from BNL in the future will not impede progress on the undulator. Assembly drawings are being duplicated and will be forwarded to Argonne concurrent with this report so that fabrication can proceed as quickly as possible. The final design review should proceed on a system by system basis to accelerate getting into fabrication. The order of system review should be as follows: the magnetic structure, C-frame structure, gap separation drive system, the floor mount structure, end correctors, controls and other systems. During the month of February over 600 man-hours were expended on this project principally in a mixture of engineering and designer/drafting again underscoring the emphasis on the detailed design at this point.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 March 1989 - 15 April 1989

Approval for the final design has been received and the completed drawing packages are being finished for complete submission to the shop. Unfortunately, progress in moving the drawings into the shop were hampered by the late arrival of critical interface drawings from Brookhaven. Specifically, areas which were impacted have been the floor stand (minor impact), the spring versus air cylinder compensation system (minor impact), and the placement of heretofore unknown flanges on the vacuum chamber (possible major impact on magnetic structure). A series of telephone conversations with BNL have resolved the first two issues. The third issue concerning clearances is nearing resolution in a fashion of minor impact, but STI was concerned to hear that the vacuum chamber had been submitted to the shop at BNL without any effort to assure that the undulator and vacuum chamber designs were fully compatible. STI has decided to employ the spring driven compensation system even though the air cylinder system is most likely the more appropriate device for the application. The pole material has been submitted for rough cutting to dimension prior to grinding. During the month of March 480 man-hours were committed to this project. Of that number of man hours, 59% was engineering, 30% was designer/drafter, and approximately 8% was scientific staff. This decrease in the total number of labor hours and change in the labor mixture is representative of the fact that the design phase is terminating and the final checking and assembling of prints is proceeding prior to fully committing to fabrication.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 April 1989 - 15 May 1989

The process of moving the drawing packages into the shop continues and fabrication is beginning. The poles are rough cut to size and final grinding and machining will soon begin. The measurement fixtures and special tooling for magnet measurement is nearing completion. Based on the latest information from Shin-Etsu concerning the magnets they should arrive at STI by the end of the May. Everything is being prepared for their arrival, inspection, and testing.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 May 1989 - 15 June 1989

All aspects of the U-5 design are into the shop and starting fabrication except the floor stand and an aspect of the spring compensation mechanism. These two aspects have been delayed by discussions with NSLS personnel, but we expect resolution of these minor points to occur quickly. All work in fabrication has been prioritized with the magnetic structure being of highest priority, the gap separation structure next priority, and remaining ancillary systems of third priority. This assures that the magnetic measurements can occur as quickly as possible.

Shin-Etsu originally quoted us a 22 June 1989 delivery date on the magnets. This last week Shin-Etsu informed us that as the result of IATA regulations being changed, they could not ship the magnets by air transport and would have to send them by climate controlled surface ship from Japan. They have informed us the name of the ship and its date of arrival at the port of Tacoma. The new delivery date for the magnets is 26 July 1989. This date is still in keeping with the original project schedules. The date will not become a problem unless delivery of the magnets should slip past 10 August 1989

During the month of May 1989 a total of 438 man-hours were devoted to the project of which 43% are engineering related to getting all of the drawings into fabrication and setting up shop schedules, and 45% of the total is machinist and technician hours.

Enclosed are some photographs of pieces of the magnetic structure in fabrication.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 June 1989 - 15 July 1989

Full fabrication continues. Final accord with NSLS personnel has been reached on the floor stand and is being incorporated into the final drawings to allow fabrication. The shop time received during this period is sufficient to assure the milestones. The majority of first priority pieces have been fabricated or are nearing completion. The first priority is all portions of the device directly associated with the magnetic structure. The magnetic bases are complete. The pole clamps are complete. The poles have had the initial grinding completed on them and are now receiving detail machining.

The magnets are still on the track with the revised schedule and should arrive the 26 July 1989. This date is still in keeping with the original project schedules. The date will not become a problem unless delivery of the magnets should slip past 10 August 1989

During the month of June 1989 a total of 751 man-hours were devoted to the project of which 81% of the total is machinist and technician hours. The balance was spent on resolving the final engineering and design issues with NSLS, and project administration, scheduling, and tracking.

Enclosed are some photographs of U-5 fabrication.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 July 1989 - 15 August

Full fabrication continues. The shop time received during this period is adequate to allow achievement of the milestones. All of the first priority pieces are nearing completion. The first priority pieces are all portions of the device that are directly associated with the magnetic structure.

The magnets have been received and initial magnetic and physical dimension acceptance testing has begun. The poles await heat treatment, but will not be sent out until it is verified that the magnets meet mechanical tolerances and will not require any machining adjustment of the pole pieces.

During the month of July 1989 a total of 576.4 man-hours were devoted to the project of which 78% of the total is machinist and technician hours. The balance was spent on some final engineering and design documentation issues, project administration, scheduling, and tracking. The total number of man-hours spent is somewhat lower for the month of July as a result of vacations and the holiday time.

Enclosed are some photographs of U-5 fabrication.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 August 1989 - 15 September 1989

Full fabrication and assembly continues. The shop time received during this period is adequate to allow achievement of the milestones. All of the first priority pieces are completed. The first priority pieces are all portions of the device that are directly associated with the magnetic structure.

The magnets have been fully tested both in dimensional tolerances and magnetic characteristics. The poles and end corrector pieces have been heat treated. Once the nickel surface coating on the magnets is smoothed they meet all dimensional specifications.

During the month of August 1989 a total of 826.5 man-hours were devoted to the project of which 79% of the total is machinist and technician hours. The balance was spent on some final engineering and design documentation issues, project administration, scheduling, and tracking.

Enclosed are some photographs of U-5 fabrication and assembly, and the histograms and results of the magnetic testing.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 September 1989 - 15 October 1989

Fabrication is nearing completion, and final assembly is beginning. The shop time received during this period is adequate to allow achievement of the milestones. Only 34 hours of backlog of machining remain before only reworks and assembly modifications occur. All of the pieces that have been completed in the shop have been sent out for anodizing, and the pieces remaining in fabrication are not required for magnetic testing. The magnets and poles have been mounted onto the magnetic structures and these assemblies will be mounted onto the support beams within a week. Assembly of the end correction coils and drive train have begun as have preparations for the magnetic measurements. Notification will be made as soon as the date for the final certification testing is made.

During the month of September 1989 a total of 791.8 man-hours were devoted to the project of which 87% of the total is machinist and technician hours. Preparations for the magnetic measurements, updating of the assembly drawings, and planning for the delivery, acceptance and installation at Brookhaven, as well as project administration, scheduling, and tracking occupied the remainder of the time.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 October 1989 - 15 November 1989

Fabrication is completed. Final assembly is completed to the point that magnetic measurement are beginning. The only assembly tasks remaining are the anodizing of the cover panels and the final wiring of the interlocks, neither of which is needed for magnetic testing. The end corrector coils have been assembled and initial magnetic testing performed on them. With a single coil mounted on the end-field/corrector assembly and energized to only 5 amperes a dipole correction field in excess of 3 kG-cm was measured. This is more than adequate for steering correction. The final magnets were adjusted to approximately 50% of the nominal field strength to properly tailor the end field configuration. This was done by heating the magnets uniformly to 165° Celsius. A preliminary test of the magnetic structure indicates that the peak field is well in excess of the 4.25 kG minimum requirement.

Magnetic testing is beginning and it is anticipated that the certification tests for witnessing by Argonne personnel will be the first week of December. As testing progresses the exact timing will become clearer and communicated to Argonne. As soon as the covers return from anodizing photographs will be taken and sent as part of the interim deliverable package defining completion of fabrication and assembly.

During the month of October 1989 a total of 464.5 man-hours were devoted to the project. The reduction in the number of hours is expected as fabrication has been completed. Only 10% of the man-hours are machinist finished the 34 hour backlog and completed some final assembly reworks. Of the remaining hours, 62% were technician and research associate related to the final assembly. The balance was spent on final as built assembly drawings, end-field and magnetic field test and configuration, and planning for the delivery, acceptance and installation at Brookhaven, as well as project administration, scheduling, and tracking.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 November 1989 - 15 December 1989

Final assembly is complete. Magnetic measurements are being made full time. The cover panels and the final wiring of the interlocks, have been accomplished.

The integrated dipole of the undulator without the corrector coils/end clamps is only 13 G-cm. The sextupole component is within the 100 G/cm integrated specification and the quadrupole moment is consistent with the 10 G integrated value, but may require some minor shimming to tune this component.

Upon assembly it was discovered that as the gap was changed the lower jaw showed a complete canting. This was traced to improper installation of the compensation springs on the lower jaw and corrected. All mechanical tolerances are now within specification.

During the month of November 1989 a total of 526 man-hours were devoted to the project. This is an increase from the number of hours from the previous month and is consistent with the magnetic measurements being under full swing. Only 7% of the man-hours are machinist or electronics technician related. 73% represent technician, research associate, and scientist hours related to magnetic measurements and the last aspects of final assembly. The balance was spent on final as built assembly drawings, and project administration, scheduling, and tracking.

ANL Contract No.: 82282401

STI Control No.: 1433

U-5 PERMANENT-MAGNET HYBRID UNDULATOR

Monthly Progress Report

15 December 1989 - 15 January 1990

Magnetic measurements continue full time. Some intermittent noise problems levels have slowed progress on definitive higher order moment measurements, but toward the end of this period several solutions are being pursued which should allow the measurements to be completed prior to the 12 February 1990 date set for the review of the measurements by Argonne personnel. Some additional fine tuning of the controls and sending out the floor supports for a final finish machining (needed only for final installation) were also worked on during this time period.

During the month of December 1989 a total of 310 man-hours were devoted to the project. This is a reduction from the number of full-time equivalents from the previous month (2.4 FTEs vs. 3.3 FTEs for November), but is understandable from the fact that all other activities associated with the undulator were completed leaving only the measurements which is only productive at a 2 FTE level. This level is consistent with the magnetic measurements being under full swing.

U-5 UNDULATOR

