BROOKHAVEN NATIONAL LABORATORY
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CRADA FINAL REPORT

DEVELOPMENT OF A SUPERFERRIC UNDULATOR
FOR ADVANCED RADIATION SOURCES

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Abstract

Under this CRADA we have carried out a joint research and development program between the Accelerator Test Facility at the National Synchrotron Light Source Department at Brookhaven National Laboratory and Northrop-Grumman Corporate Research Center of Princeton New Jersey, for the purpose of developing an advanced superferric undulator for the generation of Free-Electron Laser (FEL) radiation. The intent of this work was to enhance the performance of the superconducting microundulator recently developed at Brookhaven National Laboratory and to transfer this technology to the industrial participant that has expressed great interest in acquiring the manufacturing and physics design capabilities of this device.

Background

Accelerator based radiation sources, such as synchrotron light sources, have proved their value to the scientific community at large. Even as third generation light sources, such as the APS at ANL are being built, fourth generation sources are becoming a subject of research (for example, see the proceedings of the Fourth Generation Light Source Workshop, H. Winick and M. Chornaccia editors, SSRL February 1992).

The generation of high field, precise and easy to control magnetic undulators and wigglers are in the forefront of synchrotron radiation and FEL research, with wide ranging applications for generation of coherent radiation in the ultra violet and X-ray regimes. Brookhaven National Laboratory is one of the leading laboratories in the research and development of these sources as well as other synchrotron radiation technologies.

The National Synchrotron Light Source Department at BNL is designing a Fourth Generation accelerator-based UV/VUV radiation source that will provide picosecond and sub-picosecond pulses of coherent ultraviolet radiation for wavelengths from 300 to 75 nm. The peak pulse power is from 200 MW to over 1 GW. The UV-FEL will make possible new avenues of

inquiry in time resolved studies of diverse fields including chemical, surface and solid state physics, combustion dynamics, atmospheric science, biology and material science.

The high brightness gun, linac, high power lasers, beam lines, diagnostics and other experimental facilities of the Brookhaven Accelerator Test Facility (ATF) give it unique capabilities for exploring these important R&D areas. The FEL experiments at the ATF are specifically designed to explore the short wavelength emittance limit of compact linacs utilizing high brightness electron sources.

In FELs as well as in spontaneous emission based light sources, an essential device for generating the radiation is the magnetic undulator. The current widely used alternative is the permanent magnet undulator. The high precision wigglers and undulators based on permanent magnet technology carry a high price tag due to the inherent technology of constructing a complex field pattern from a collection of many blocks of magnets that have a rather large spread of magnetization as manufactured. Another contributor to the price tag is the high precision mechanical device that is needed for tuning the field over a large range.

Significant accomplishments

A new beam line has been built at the Brookhaven Accelerator Test Facility, providing an electron beam transport and laser systems injection pathway at its experimental hall for the on-line testing of the undulator. Special diagnostic has been developed for this beamline. Cryogenic services and dc power and coil protection circuitry have been designed and mostly constructed.

Extensive POISSON 2d and TOSCA 3D numerical modeling of the undulator performance and dependence on various parameters such as geometry and saturation. In particular modeling has been done on the parabolic pole tip shaping that provides two plane focusing. Magnetic circuit for the transitions between the individual yokes that make up the undulator assembly has been developed.

Engineering design and drafting of the undulator components, including its cryostat has been made.

The special Hall Probe magnetic measurement device for testing of the assembled undulator in its cryostat has been designed and built.

The undulator parts, comprising the modulator section, the dispersive section and the six piece radiator has been precision machined.

The undulator holder has been built to extremely tight tolerances.

The cryostat has been built and cryogenically tested.

The prepping and winding of the undulator yokes has been done and checked.

A cryogenic magnetic measurement test setup has been developed for precision testing and characterization of undulator sections.

All the undulator subsections have been tested and characterized.

The complete undulator system has been assembled into the cryostat and is ready for its first cool-down.

Significant problems

No single significant problem has been encountered. Due to various small problems the timetable of the project has slipped considerably, however the undulator is ready at this time for a final test.

Industry benefits realized

Northrop-Grumman acquired knowledge and the manufacturing and physics design capabilities in the areas of superconducting ferromagnetic based undulators and Free-Electron Laser technology.

The modeling of the steering errors and techniques of correcting them have been improved significantly. A satisfactory understanding of the advanced superferric undulator design has been attained. In particular we established the technology and manufacturing basis for the production of high precision, high field and fast tuning undulators and wigglers.

High precision, dc, electronically adjustable low cost undulators and wigglers will be required for the next generation of light sources for basic energy science research as well as for a number of commercial accelerators and Free-Electron Lasers for commercial applications such as material processing, lithography and medicine. Scientific applications include chemistry (in particular photochemistry of combustion dynamics, atmospheric processes such as ozone generation and depletion, greenhouse gas and acid-rain atmospheric chemistry), material science and more. The technology developed in this research could be utilized in the development of a tunable, high power UV FEL as a commercial product and in future commercial Free-Electron Lasers.

Laboratory benefits realized

BNL verified its theoretical undulator models and answered questions such as the effect of geometry, conductor and winding method on the performance of the complete system. The undulator will be a basis for FEL physics experiments as well as future FEL programs in the laboratory, such as the proposed UV FEL Facility.

Recommended follow-on work

The superconducting undulator technology that has been developed at BNL and at Northrop-Grumman has a great future potential. Synchrotron Light Sources are widely used by most scientific disciplines. Free-Electron Laser technology is emerging as the technology of choice for the next generation of accelerator based radiation sources. The magnetic undulators and wigglers are needed equally well by storage-ring based spontaneous emission sources as well as Free-Electron Lasers. A device with a significant performance to cost ratio will have an impact on both. In addition, the NSLS has successfully demonstrated that a small gap undulator can be inserted into the X-ray ring without compromising the stored beam lifetime. It is recommended that a very short period, small gap undulator will be developed as an insertion device for the storage ring and for future short wavelength FELs.