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13. ABSTRACT (Maximum 200 words) The following task was accomplished: 1. Determine the optical strengths and sensitivities of the quadrupole and sextupole magnets of the ring, and review requirements for the software control system. 2. Analyze the design the synchrotron radiation absorbers and vacuum components for the FEL and synchrotron radiation straight sections of the ring, 3. Design and assemble the remaining components and subsystems of the proposed UV/XUV storage ring and linac, and 4. Install and test these components in the new Duke FEL Laboratory.				
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Final Technical Report for AFOSR Contract Number F49620-88-C-0100. "Research on a UV/XUV Storage Ring and Linac"

The statement of work for this contract specified that Duke should:

1. Determine the optical strengths and sensitivities of the quadrupole and sextupole magnets of the ring, and review requirements for the software control system,
2. Analyze and design the synchrotron radiation absorbers and vacuum components for the FEL and synchrotron radiation straight sections of the ring,
3. Design and assemble the remaining components and subsystems of the proposed UV/XUV storage ring and linac, and
4. Install and test these components in the new Duke FEL Laboratory.

The status of these tasks and the other research conducted with the support of this contract is summarized below.

Review of Optical Strengths and Sensitivities of the Ring Magnets: The magnetic lattice of the ring has been simplified by removing the discrete sextupole magnets and "noses and dimples" which had been part of the poles of the dipole magnets. The coupling between these elements at the magnetic fields required for operation at 1 GeV and above resulted in the saturation of the yoke and pole tips of the sextupole magnets and an intolerable level of distortion of the sextupole field.

To supply the sextupole field required to correct the chromaticity of the quadrupole focussing magnets, it was found that the coils of the sextupole magnets could be excited asymmetrically to add a sextupole component to the quadrupole field in these magnets. Though previously demonstrated in the LURE laboratory at Orsay, this technique has not previously been used in the United States. In addition to the elimination of the prior problems with yoke saturation, this solution actually improved the performance of the ring by physically moving the fields required for compensation of chromaticity to the quadrupole magnets responsible for this phenomenon.

Provisions have also been made to add specially shaped thin magnetic shims to the interior pole faces of the dipole magnets to provide the small additional chromaticity correction required to optimize the dynamic aperture of the lattice. The shims can be changed quickly to permit reconfiguring the dipoles to accommodate possible future changes in configuration.

Requirements for Software Control System: Following a general review of the control systems requirements for the Laboratory, including in particular the parallel control systems requirements of the Lab's UV/XUV, synchrotron radiation and Infrared FEL systems, it was decided to adopt the EPICS control system which has been developed for the Ground Test Accelerator (GTA) project at Los Alamos and for the Advanced Photon Source (APS) synchrotron light source at Argonne. Beyond the advantages which this system will bring to the FEL Laboratory, the use of a common control system shell will make it possible to provide the GTA and APS projects with the controls system capabilities which are being developed at Duke to automate accelerator and beamline operation.

Synchrotron Radiation Absorbers: The distribution of synchrotron radiation within the arcs and straight sections of the ring was re-analyzed based on the new magnetic lattice. The existing synchrotron radiation absorbers in the arcs were found to be adequate to support operation at full energy and current. A simplified system of synchrotron absorbers was designed for the straight sections to accept the radiation anticipated during commissioning. The straight section absorbers will be replaced as required to accommodate the installation of the undulators planned for the straight sections and the evolution of operational capabilities.

Completion and Assembly of Remaining Components Required for the Ring and Linac: Most of the components for the ring and linac had been fabricated at Stanford, and were shipped with the rest of the Laboratory's research equipment to Duke. The remaining major components required for these systems included the high power RF cavity and transmitter for the ring, the special magnets required to transport and inject the electron beam into the ring, and the microwave gun for the linac.

After reviewing the options for the design and development of the high power RF cavity for the ring, it was decided to purchase an assembled RF cavity from the Institute of Nuclear Physics in Novosibirsk. The specifications for the Duke cavity were very close to the specifications for a new cavity being mass produced at the INP for one of its own FEL programs; following detailed discussions, the INP was able to modify one of these new cavities to match Duke's specifications at a favorable cost and schedule. The production schedule for the RF cavity calls for its shipment to Duke in the fourth quarter of 1992.

As the INP cavity will operate at a frequency of 178 MHz, it also became possible to use conventional VHF tetrode technology to achieve the RF power required to drive the cavity. For the Duke laboratory, this technology is especially attractive as it employs off-the-shelf components which are available on a replacement basis at very low cost in comparison to the klystron technology required for operation above 200 MHz. Following an evaluation of vendors, an order for the transmitter was placed with QEI, Inc, who recently delivered a similar transmitter to the Brookhaven National Laboratories.

The development of the special magnets required for injection into the ring continued through the conclusion of this contract. The most challenging of these magnets are the three fast kicker magnets which deflect the orbit of the circulating electrons to permit the injection and capture of additional charge into the circulating, stable bunches. While the delay in the development of these magnets poses some risk to the schedule of the project, it is clear that the materials and technology required for these magnets and their fast-pulse drivers has continued to evolve, and that performance and reliability will be enhanced by taking advantage of the ongoing advances in the state of the art.

Finally, with respect to the new microwave gun required for operation of the linac, a prototype version of this gun has been developed with independent contract support by Professor Jones at NC Central University with the advice and consultation of the scientific and engineering staff of the FEL Laboratory. If this design proves successful, it will be duplicated for use on the Duke Linac.

In addition to the development of these specially engineered components, the Laboratory also completed the development of a number of other general purpose research systems during this period including the circulating and temperature-regulated DI water cooling systems for the linac, ring and MkIII FEL, a number of electrical distribution systems for these devices, and the design and installation of radiation shielding and personnel protection systems in the linac tunnel and MkIII FEL vault.

Installation and Test Activities: Our installation and test activities have continued through the conclusion of this period with emphasis on magnetic measurements of the revised quadrupole and dipole magnets, and on the common hardware and software control systems for the linac modulators and the MkIII infrared FEL.

The integration of the components for the ring and linac has continued to run approximately 6-12 months behind schedule due to delays in the occupancy of the new FEL Laboratory building and the re-design of the lattice for the ring. While adequate progress has been made in the bench tests of the existing components, and in the specification and procurement of the additional components required to complete the ring and linac, it is likely that system integration and the initiation of commissioning activities will be delayed until the third or fourth quarter of 1992.

Other Research Activities: Theoretical research has continued through this period on the exploitation of novel interaction mechanisms for the production of coherent and quasi-coherent soft and hard x-radiation. In the soft x-ray region, it appears that useful levels of gain and power output can be achieved through the use of the "phase-displacement" amplification mechanism described and documented by Kroll, Rosenbluth and Morton. Using a short undulator spontaneous radiation source to create an initial seed pulse at the desired operating wavelength, a long inverse-tapered undulator can be used to achieve single pass gains in excess of 1000x and peak output powers of the order of a megawatt. Assuming the design parameters of the Duke ring, it appears that such a configuration is capable of producing useful levels of power for such applications as holographic imaging in the water window between 40 and 50 angstroms.

Detailed analysis has also been carried out of the characteristics and capabilities of inverse compton scattering as a source of hard x-rays in the 1 - 100 KeV region using the circulating beam in the Duke ring and an intense, focussed mm-wave pump. The brightness of such a source appears to be intrinsically superior to that of conventional high field and high energy bend magnet and wiggler x-ray sources. In view of the superior capabilities of this approach, efforts have been begun to develop a design for an x-ray microprobe microscope in conjunction with the analytical microscopy group in the Department of Cell Biology in the Medical Center.

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