ALIGNMENT OF DUKE FREE ELECTRON LASER STORAGE RING AND OPTICAL BEAM DELIVERY SYSTEM

Mark Emamian, Nelson Hower
FEL Laboratory, Physics Department, Duke University, Durham, NC 27708, USA

1. Abstract

Duke Free Electron Laser Laboratory (DFELL) hosts a 1.1 GeV electron beam storage ring facility which is capable of generating beams in the range of nearly monochromatic gamma rays to high peak power infra red (IR) laser. In this report specifications and procedures for alignment of OK-4 /Duke storage ring FEL wiggler and optical cavity mirrors will be discussed. The OK-4 FEL lasing has demonstrated a series of world record in the last few years. in August of this year the OK-4 FEL successfully commissioned to lase at 193.7 nm. Also in this article, alignment of the γ-ray and UV optical beam delivery system that is currently in progress will be described.

2. INTRODUCTION:

The commissioning of the 1 GeV Duke Storage Ring began in November of 1994 with the demonstration of injection, storage and ramping to 1 GeV at the first attempt [1]. Alignment procedures and methodology of the ring magnets was presented in the Particle Accelerator Conference (PAC) in May of 1995 [2]. Since then, Duke Free Electron Laser Laboratory (DFELL) has added two cavity mirrors for UV Laser, their associated beam lines in the south straight section, a UV Optical Klystron (OK-4) electromagnet wiggler designed and manufactured by the Budker Institute of Nuclear Physics, an X-ray permanent magnet undulator donated by the National Institute of Standards and Technology (NIST), its associated X-ray beam line (see Fig. 1) and a water cooled optical periscope to reflect the spontaneous radiation near the south east optical cavity. We are also in the process of installing UV and γ-ray beam lines in the newly constructed W. M. Keck building adjacent to our original FEL lab.

To satisfy the extraordinary stability requirements for research in the UV and γ-ray, the main storage ring's 1 meter thick slab is supported on a matrix of 32 closely spaced caissons extended to the underlying bedrock. The rest of the facility, including the cavity mirrors, are installed on separate slabs with thickness ranging from 12 to 32 cm.

Several optical instruments and alignment tools were used to accomplish the task of alignment. A list of these instruments and tools is as follows:

a. Brunson 76-RH Telescopic transit square, used to align components in a vertical plane.
b. Brunson 376-RHN Universal transit square, to perform the dual functions of telescopic transit square and line scope to turn right angle.

c. Wild precision sight level model N3, used to sight in horizontal plane and set elevations of components.
d. Wild precision optical plummet model NL, used for nadir plumming.
e. Brunson 803 invar scale extension kit, to measure distances of less than 7 meters.

In this article, Alignment procedures and means of vibration dampening of some of these new components and beam lines will be discussed.

2.1 Alignment of the OK-4 Wiggler

The OK-4 Wiggler was transferred to Duke FEL lab in the summer of 1995 from the Budker Institute for Nuclear Physics in Novosibirsk, Russia. It was installed, aligned and successfully commissioned in the fall of 1996. This device consists of two sections each having 33.5 periods, and each period with 10 cm in length. The gap between upper and lower jaws was modified to 2.25 cm to accommodate a new vacuum chamber designed at Duke FELL. A buncher magnet was installed between the two sections of the wiggler.

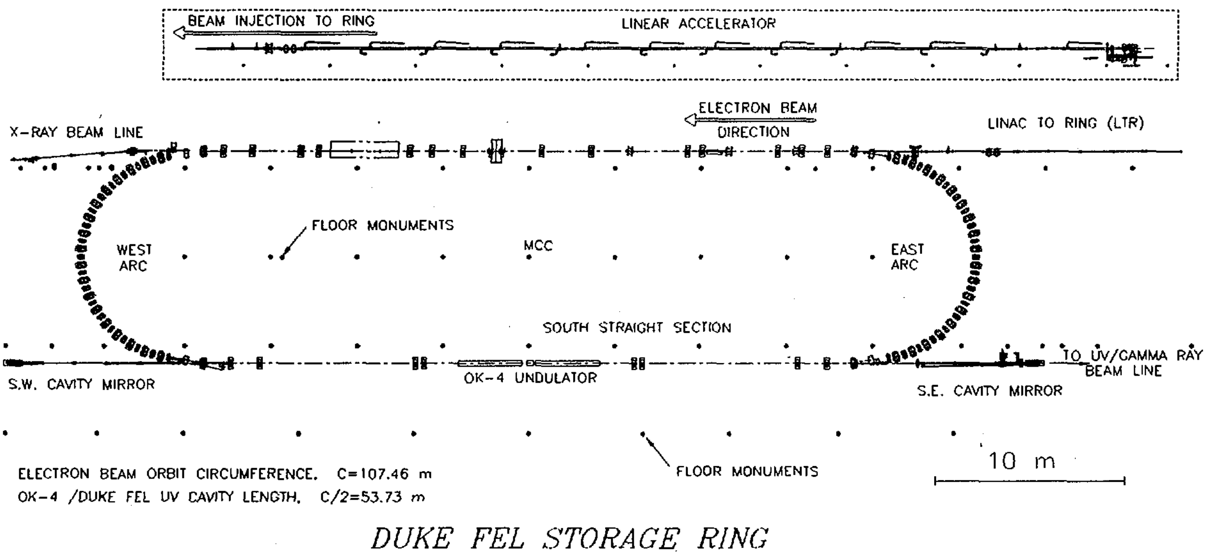

Figure 1 - Layout of the Duke FEL Storage Ring and 280 MeV Linac Injector

To align the OK-4 Wiggler sections, the bottom halves of each section were first mounted on the south straight section girder via three x, y, z adjustable mounts, and two intermediate c-channel cross bars (for additional support). Pole tips were primarily used to set the height (y direction) to an accuracy of ± 0.05 mm. To position the wiggler in x (transverse) and z (direction of beam path) direction, sides of its yoke were used as fiducials. Once the bottom halves were aligned, the wiggler's vacuum chamber was installed and the top halves of the wiggler section were lowered onto the bottom halves, with their pole tips matched to the corresponding pole tips of the lower jaws. Spacers were used between the top and bottom pole tips to set the distance between the two pole tips at a fixed distance of 2.25 cm. Nearest floor monuments were used as reference points with the aid of the alignment instruments mentioned above to accomplish this task. A similar method was used to align the buncher magnet.

2.2 Alignment of the OK-4 FEL Optical Cavity

Each OK-4 FEL optical mirror cavity assembly consists of a Newport, SLA series mirror mount which is holding a 5 cm diameter concave (R=27.27 m) mirror. This assembly is mounted on a honeycomb optical table via three 2.5 cm thick steel base plates to manipulate the positioning of the mirror mount. Four dowel pin bushings (2.5 cm in diameter) are mounted on four corners of the top base plate near the mirror mount. The distances from the center of these bushings were accurately measured with respect to the center axis of the mirror mount. The distances between downstream and upstream mirrors were determined through these sets of bushings and the floor monuments along the south straight sections. Brunson invar rods and transit along with a wild precision sight level were used to establish the length of the optical cavity at one half of the storage ring's circumference (53.73 m) to an accuracy of ± 0.25 mm.

To reduce vibration of the cavity mirrors, the concrete slabs around the perimeter of both optical boards were cut off from the main floor [3]. Nevertheless, nearby moving equipment, staff walking by and vehicles driving in the proximity of the lab have caused minute, but unacceptable, levels of vibration and angular displacement. To resolve this issue, a unique optical feedback system was designed and successfully implemented [4].

2.3 Alignment of the γ-ray and UV optical beam delivery system

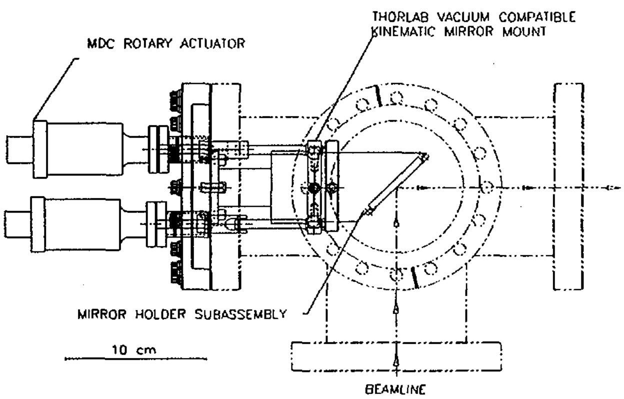

Figure 2- Optical Mirror Assembly. In this design, each MDC actuator is coupled with a kinematic mirror mount via a long, fine adjustment screw to provide steering of the laser beam in horizontal and vertical direction.

In January of this year construction of a 13000 SF facility was completed to host a variety of experiments with gamma ray, vacuum ultraviolet (VUV) and infrared in the area of medical, materials science and nuclear physics. Duke FELL's new expansion is capable of hosting a minimum of 25 user lab facilities.

A high energy polarized γ-ray beam is generated in the south straight section of the storage ring through head on collision of relativistic electrons and photons generated by the OK-4 / FEL [5]. Various unique nuclear experiments have already been done with γ-ray beam at Duke FELL. We have just installed a large γ-ray detector on the first floor of the Keck expansion and are currently in the process of installation and alignment of the γ-ray beam line using the conventional methods described previously.

The design of the UV beam line assembly is underway; some of the components such as mirror holder cavities have been designed and fabricated (see Figure 2). At present we plan to do most of the fine alignment of the optical mirrors through unique features that have been designed in these mirror holder assemblies.

Vibration on the second floor of the Keck life and science building is believed to be a significant obstacle to overcome in delivering laser to scientists who perform life science experiments. An air handling unit is installed on the roof of the building which is believed to be the main source of the vibration. We are currently in the process of analyzing the vibration issue and hope to improve stability of the beam delivery system soon.

3. References:

[1] V.N. Litvinenko, Y.Wu, B.Burnham et al. ,"Commissioning of the Duke Storage Ring" in proceedings of the 1995 Particle Accelerator Conference, Dallas, Texas, p.213.

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[4] I.V. Pinayev, M. Emamian, et al. "System for Control and Stabilizing of OK-4 / Duke FEL Optical Cavity" presented at the 8th Beam Instrumentation Workshop, May 4-7, 1998.

[5] V.N. Litvinenko, B. Burnham, M. Emamian, et al. , Gamma Ray Production in a Storage Ring Free Electron Laser in Physical Review Letters, V. 78, No.24, June, 1997, p4569.