STATUS OF MARK III FEL*

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Abstract

Current status of Mark III free electron laser and its upgrades are presented.

1 INTRODUCTION

The Mark III free electron laser (FEL) was first put in operation in 1985 at Stanford University [1]. After relocation to Duke University it was successfully re-commissioned [2].

Aging of the machine components made the Mark III less reliable, necessitating upgrades. The additional reasons for modifications are to bring it up with up-to-date technology, to have a fully automated control and to improve optical beam quality.

1 RF SOURCE

The RF system is the heart of the machine. It employs 40 MW klystron with 10 •s modulator. This system defines most FEL parameters and the majority of the improvements will concern this system.

A new Hewlett-Packard synthesizer, replacing the old master oscillator, provides better means of regulating of the RF system. In the nearest future we want to implement a new master oscillator, which will have electronic tuning for computer control. This unit will have auxiliary input for amplitude modulation, which will be used for the fine tuning of the FEL.

At present, an old high voltage source, utilizing unregulated rectifier, was replaced with power supplies manufactured by Maxwell. 100% fluctuations of the optical power caused by the variations of high voltage were reduced to the 2% r.m.s. value (5% peak-to-peak).

This upgrade revealed that machine protection system (MPS), inherited from Stanford, was prone to pick-up noise induced by the pulse forming network (PFN) discharge. Fault trips, occurring minutes apart, compromised user applications. A new MPS based on the programmable logic controllers provides better protection, more flexibility, and allows us convenient troubleshooting.

The old system for SAS61 klystron preamplifier will be upgraded to provide more uniform RF excitation as well as an increase of the operation safety. We expect that these measures and the new coils of the PFN will provide less then 0.1% ripple on the flat top, allowing significant increase of the macropulse energy of the Mark III FEL.

Replacement of a fixed coupler with a variable power splitter, which has remote control, will allow faster change of a lasing wavelength. Implementing a potentiometer read-back with servo amplifier will bring the RF system under full computer control.

2 MAGNETIC SYSTEM

2.1 Accelerator Magnets

The magnetic system, which defines electron beam transport, also affects stability and reproducibility of the FEL. Many years of operation showed reliability of the majority of magnets themselves (we had only one failure of steering magnet). However, Digiplan power supplies, which are dedicated for operation with the DC motors, need to be replaced. They are prone to the overheating and have significant drift. Unipolar Kepco power supplies are robust and stable but can develop dangerous voltage in the absence of load and they will be replaced too. We have considered utilizing custom made power supplies used for the steering coils at the Duke storage ring. They proved their quality and will help to upkeep uniform environment on both machines, thus reducing number of spare modules. Old high current power supplies used to feed beam dump magnet, spectrometer magnet, and •-magnet will be replaced with the new ones. A few obsolete steering magnets will be removed while new XY pair will be installed in front of the wiggler.

Eight chicane magnets employing permanent magnets with the magnetic shunts will be replaced with the electromagnets fed in series. This will eliminate need in individual tuning of the magnets and simplify change of the accelerator energy.

2.2 Wiggler

The Mark III FEL utilizes hybrid planar undulator with SmCo permanent magnets [3]. Before installation magnetic measurements of the wiggler and tune-up were done. During the upgrade of vacuum chamber (see below) we want more precisely map magnetic field and re-tune the undulator if it is needed. Correction of the remaining field integrals will be done with the help of the steering magnets. LVDT read-back will be added for diagnostic purposes.

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3 OPTICAL SYSTEM

3.1 Optical Cavity

The optical cavity defines quality of the FEL radiation. Currently the Mark III implements two broadband metallic mirrors with an intracavity Brewster plate used for outcoupling of the optical power. This approach was adopted for full utilization of wide tunability of the Mark III FEL. It proved itself by many years of operation. However, this approach has significant disadvantage. It has multiple optical beams coming from the optical cavity. It can also distort TEM_{00} mode of optical cavity.

Therefore, we decided to follow design of the FEL installed at Vanderbilt University. Their optical cavity has one metallic mirror and a set of the *in situ* interchangeable mirrors with dielectric coatings. Some modifications of this design will be done, for example a carousel, used for changing mirrors, will also provide possibility for alignment of the optical cavity in one direction. Alignment in the transverse direction will be performed by a rotary stage.

A broadband metallic mirror will be installed downstream behind the beam dump magnet in a gimbal mount placed on a translation stage. Stepper motor actuators will provide precise control. Four LVDTs will provide information about current position of the mirrors.

We want to reduce the Rayleigh range of the optical cavity. Two goals will be reached: a net gain is expected to be higher and the power density on the cavity mirrors will be lower.

3.2 Beam Delivery System

After changes in the radiation shielding one elbow in the beamline was removed, reducing number of reflections, making it more straight and stable. A new pipe was added to the beamline to deliver light to the users in a new research building.

Supports of two crosses were significantly rebuilt for substantial increase of stability. Improvements in the vacuum system considerably reduced leaks and allowed installation of a turbomolecular pump.

Beamline transmission will be noticeably improved after installation of a spherical concave mirror. It will match Rayleigh range of the optical beam with beamline length and reduce size of the beam.

4 OTHER SYSTEMS

4.1 Vacuum System

Old power supplies for ion pumps were replaced with the new ones manufactured by Physical Electronics. The ion pumps, which almost exhausted their service time, will be replaced in the nearest future. Some elements of the vacuum chamber prone to the leaking will be replaced.

The major upgrade will concern wiggler vacuum chamber. Welded aluminum started developing cracks, causing vacuum leaks. New design of optical cavity will employ aluminum extrusion chamber with braised steel flanges.

4.2 Control System

The Mark III control system is based on the Experimental, Physics and Industrial Control System (EPICS). Currently installed version 3.09 is obsolete and we plan to upgrade it to the latest release of EPICS. Changes in the database will reflect hardware modifications by deleting the unused input/output channels and creating new controls, replacing manual knobs. We also consider replacing of all CAMAC modules with VME analogs.

Some old “home-made” modules will be replaced with commercial units. For example new timing system will employ VME modules manufactured by Berkeley Nucleonics.

4.3 Diagnostics

The diagnostics of Mark III will be upgraded by replacing existing viewers with YAG:Ce screens. This will increase resolution. New cameras and viewports replaced the ones damaged by radiation. New monochromator with linear detector easily obtains the infrared spectra of the FEL.

5 CONCLUSION

The upgrades of Mark III FEL significantly improved its performance. Further modifications will make it a more user-friendly facility.

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