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PROPOSAL FOR A FAR-INFRARED FEL AMPLIFIER EXPERIMENT AT ISIR, OSAKA UNIVERSITY

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Abstract

It is proposed to carry out FEL amplifier experiments in the 100 μm wavelength region using a CO_2 laser pumped CH_3OH laser as the optical input source. The experiments are to be conducted on the existing 38 MeV, L-band linac based FIR FEL system at the Institute of Scientific and Industrial Research (ISIR), Osaka University. This paper describes the experimental layout of the proposed scheme and the details of FIR input laser proposed to be used. The results of numerical estimation of the single-pass output power of the system are also given. We are currently in the process of procuring the necessary components for this experiment.

1 INTRODUCTION

The Free-Electron Laser (FEL) has been extensively used in recent years to produce light in various wavelength regions ranging from the microwave to the ultraviolet radiation using a variety of accelerators such as Van-de Graff's, RF linacs and storage rings. Self Amplified Spontaneous Emission (SASE) is a FEL phenomenon which occurs when, under certain conditions, an electron beam passing through a wiggler self-bunches due to interaction with its own radiation field to produce radiation [1]. It is essentially a single-pass process where the initial random field of spontaneous radiation is amplified in intensity and enhanced in coherence characteristics as it interacts with the electron beam along the wiggler region.

One of the major applications of the FEL is its ability to amplify input optical radiation. Unlike the SASE radiation, in which the signal startup is from noise, the high single-pass gain in the FEL can be used effectively to amplify an input radiation of relatively small power.

The use of single-pass FEL amplifiers without an optical cavity will be advantageous in the quest for generation of FEL laser of high gain and short wavelengths where use of conventional mirrors would be impractical. The FEL in the amplifier mode offers another viable method to obtain high power FIR radiation that otherwise would not be available from commercial FIR laser sources.

SASE was first observed here at the Radiation Laboratory of the Institute for Scientific and Industrial Research (ISIR), Osaka University in 1991 during the course of developing the infra-red FEL using the 38 MEV L-band linac [2,3], and since then, the SASE output wavelength has been extended beyond the 100 μm region and extensive research work is currently being carried out to characterize the SASE. Oscillation experiments have also been carried out in the FIR region using this FEL system.

This proposal is aimed at examining the performance of the existing ISIR FIR-FEL in the amplifier mode and also to verify results of the simulation codes. In this experiment, the input FIR laser radiation acts as the seed photon which is amplified by the electron beam traversing through the wiggler. The results are expected to help us

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understand better, the phenomenon of SASE and the FEL amplifier.

2 EXPERIMENTAL SETUP

The 38 MeV ISIR linac is capable of delivering a high- intensity, single bunch beam of charge up to 73 nC and with a pulse length in the range 9-50 ps. The electron beam is delivered to the FEL system *via* the beam line that uses two bending magnets and a series of quadrupole magnets.

The FEL system consists of a Halbach type, permanent magnet (Nd-Fe-B) planar wiggler having 32 periods of 60mm period. The wiggler gap can be adjusted from 30-120mm and hence the wiggler constant K can be varied from 1.47 to 0.013. The length of the optical cavity of the system is 5.532m and is used for FEL oscillation experiments [4]. For the single-pass experiments, the mirror on the downstream side of the beam would be removed to extract the amplified radiation. The input source as well as the detection system for the amplified output radiation would be located outside the shield wall of the linac room and the input as well as output optical beams would be transported *via* evacuated light pipes to eliminate atmospheric attenuation. The control of the FEL beam line and the wiggler gap adjustment are done using a simple, computer controlled system [5].

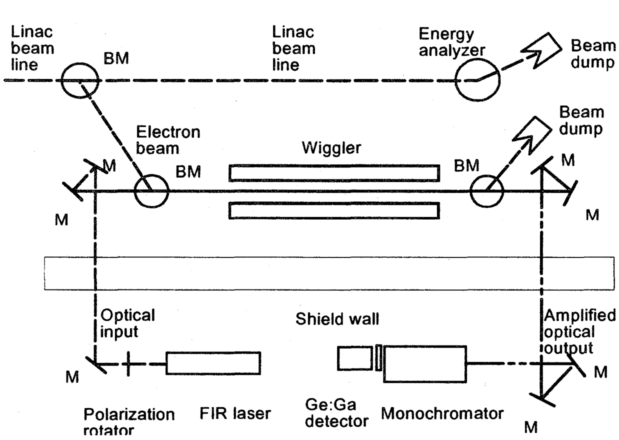

Fig.1. The schematic diagram of the proposed FIR-FEL amplifier experiment.

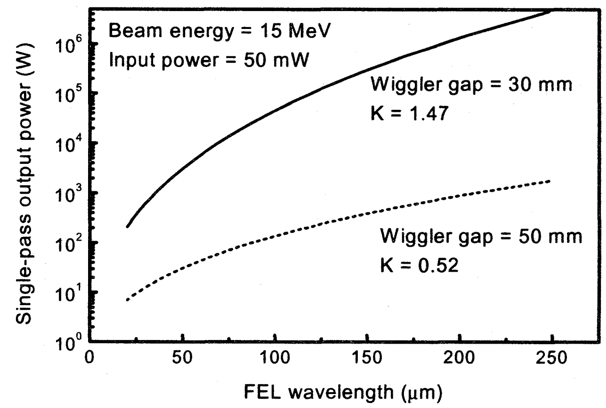

Fig.2. Dependence of single-pass output power on FEL wavelength

The schematic diagram of the proposed experimental setup is shown in Figure 1. The FIR laser proposed to be used as the input source is a commercial CO_2 laser pumped alcohol (CH_3OH) laser lasing at 96.5 and 118.8 μm when pumped by the 9R10 and 9P36 lines of the CO_2 laser respectively. Typical optical powers of 60 and 120 mW respectively are available for injection into the FEL amplifier system at the above mentioned wavelengths.

Initially, we propose to conduct the amplifier experiments at the two FIR wavelengths mentioned above, but in the future, when the linac beamline is modified to deliver electron beam with energies capable of generating FEL wavelengths in the IR, the CO_2 laser wavelengths from the pump laser will be used for amplifier experiments.

The amplified signal will be detected using a grating monochromator and a liquid helium cooled, fast Ge:Ga detector which can detect radiation up to a wavelength of ~ 150 μm. Since the electron bunch length is short (20-30 ps) and the response time of the detector is ~ 140 ns, the output of the detector will essentially be a time averaged value of the amplified signal. In order to study the bulk optical output, the grating will be replaced by a mirror. Calibrated Teflon sheets will be used to attenuate the optical signal so that the detector output is kept well below saturation.

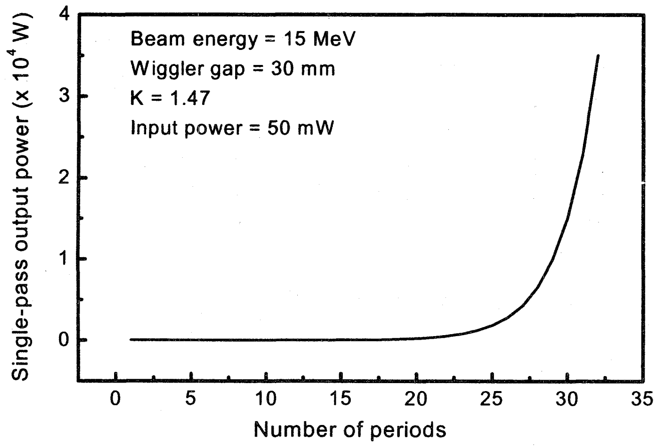

Fig.3. The growth of the single-pass output power with number of wiggler periods.

The initial experiments will involve estimation of the gain profile of the FEL amplifier by measurement of the input and output optical powers at the resonance wavelength. The dependence of the gain on beam current, FEL resonance wavelength and polarization angle of the input FIR radiation will also be studied.

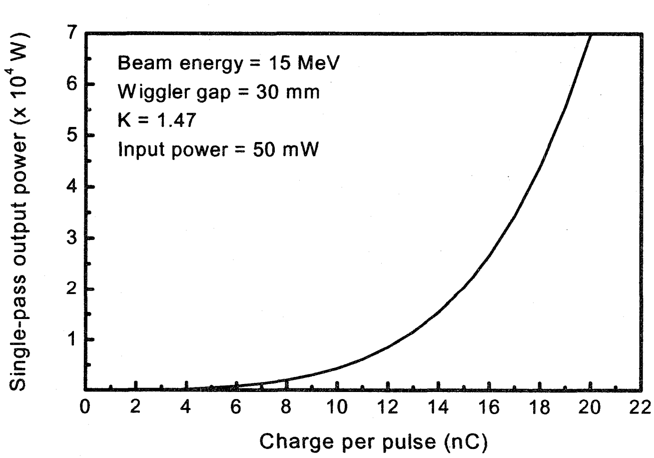

Fig.4. The dependence of the single-pass output power on the charge of the electron beam.

Simple numerical estimations of the gain of the proposed system were also carried out and are graphically represented. Fig. 2 shows that FEL system has a relatively high single-pass power gain over the FIR wavelength region of interest. The single-pass gain is a function of the interaction length, the FEL parameter (ρ), and the FEL resonance wavelength. The dependency of the signal intensity on the interaction length or number of periods is shown in Fig.3. The exponential growth of the intensity is evident after about 20 periods. The magnitude of the signal decreases as the wiggler constant K is decreased. Figure 4. shows the dependence of the single-pass power on the charge per pulse or the beam current. The charge per pulse can be varied by introducing a spatial filter (slit) in the beam line which effectively varies the charge in the electron beam.

CONCLUSIONS

The proposal for conducting FEL FIR amplifier experiments on the existing FIR-FEL at 96.5 and 118.8 μm wavelength using a CO_2 laser pumped alcohol FIR laser as input source are discussed. These experiments would enable us to understand the performance of the FEL system in the amplifier mode. We are currently in the process of procuring the necessary components for this experiment.

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