# FREE ELECTRON LASER AMPLIFIER EXPERIMENT BASED ON 3.5 MeV LINEAR INDUCTION ACCELERATOR

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## INTRODUCTION

Millimeter wave FELs have used beams produced by induction linac [1],[2],Van de Graff accelerator[3],and pulsed diode machines[4].The distinct advantage of the induction linac is its high peak power,capability of producing high current,high energy electron beams with pulse durations ranging from tens of nanoseconds to microseconds. The induction linac at our institute is of 2.5kA,3.5 MeV,90 ns(FWHM) and built in 1991.This accelerator is designed to drive the SG-I free electron laser at our institute for studying the basic physics of FELs.The SG-I facility is divided into three regions, the accelerator ,the beam conditioning section and the interaction region. After the FEL experiments in 1993,in order to satisfy the needs for the FEL experiments and achieve high power FEL output,many modifications have been carried out in the beam conditioning section and RF input way ,resulting in the increase of the current entered the wiggler and microwave output. In this paper the 3.5 MeV LIA and modifications to the linac have been briefly described.Then the FEL experiments and their results are also introduced.Finally discussions on the experiments have been given.

## DESCRIPTION OF THE SG-I FEL

### *A.The Linear Induction Accelerator*

The 3.5 MeV linear induction accelerator mainly consists of a 1 MeV injector and 8 identical induction accelerator cavities which are arranged in four module blocks.Each cavity is energized by a Blumlein pulse forming line.Twelve Blumlein PFLs are divided into two groups which are charged through twelve inductances by two Marx generators individually. Each module of the injector is applied to 250kV for a 90ns FWHM pulse.The voltage contributions of the four modules are summed along the hollow steel stem to drive the diode .The surface of the cathode is covered by velvet cloth , the anode aperture is closed off with fine tungsten mesh.

The output beam of the injector is guided through the accelerating cavities by a near-continious array of solenoids that are positioned both internal and external to the accelerating elements.Each accelerating cavity can give about 300 keV of energy to the beam.

### *B.The FEL Experiments*

As we know,the output power of FEL is proportional to the amount of electron beam current which can be trapped in the ponderomotive well,and depends on the brightness of the electron beam as well as the size of the ponderomotive well.In order to obtain a sufficiently bright beam,many modifications have been made. An apparent improvement is made on the beam conditioning section ,the mechanical and magnetic axes have been adjusted carefully and 2-m long conditioning section which consists of three solenoids and one thin magnetic lens has been used. Fig.1 is the experiment arrangement of SG-I FEL.

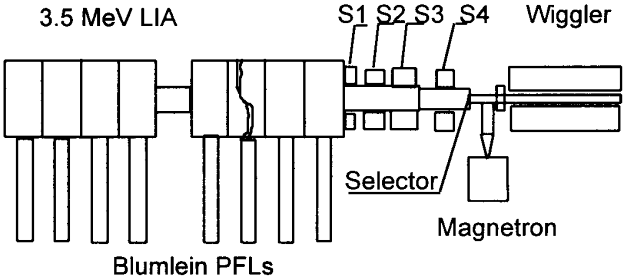

Fig.1 Schematic of the SG-I FEL

Solenoids S1 to S3 are used to transport the beam and S4 focuses the beam to the wiggler field .The space and energy sweep selector is used to provide a well-characterized electron beam for SG-I.The 4-m-long electromagnetic wiggler is composed of specially shaped solenoids with 11 cm period.The pulsed wiggler can provide a peak magnetic field on axis of 3 kG.Each two periods of the wiggler is energized by a separate power supply which allows variation of the strength and the longitudinal profile of the wiggler field.The interaction region consists of a thin-wall stainless steel oversized waveguide(3x10cm),which allows for good penetration of the wiggler field.In the second stage of the SG-I FEL experiment,the beam from accelerator is directly guided and focused into the interaction region after simply conditioning .After being confined , the beam focused transports into the wave guide through the space and energy sweep selector positioned at the entrance and interacts with the wiggler magnetic field to produce the FEL.The input microwave signal to the amplifier is provided by a 34.6 GHz,20 kW pulsed magnetron (pulse length= 500ns).The input signal is injected into the interaction region by means of a waveguide tapers whose angle with the beam line is 90 degree.

## EXPERIMENT RESULTS AND DISCUSSION

Modifications to the beam conditioning section and RF input result in the increase of the current and microwave power entered the interaction region. The beam electron energy has been measured with magnetic analyzer to be 3.5 MeV with 1% spread at 1 m from the accelerator output.The emittance is measured to be 0.4 cm-rad with a detector consisting of a pinhole mask and screen spacing 150 mm downstream, the beam brightness is EMBED Equation . The beam current at upstream of the wave guide is measured 2.5 kA with a CVR(current view resistor). The input current into the wave guide is measured 950 A with a Faraday detector., The beam currents in the interaction region are measured with a movable Faraday detector at different positions in the wiggler,and saturated power of 50 MW microwave output has been obtained ,tapered operation results in 140 MW output ,as shown in Fig.2.

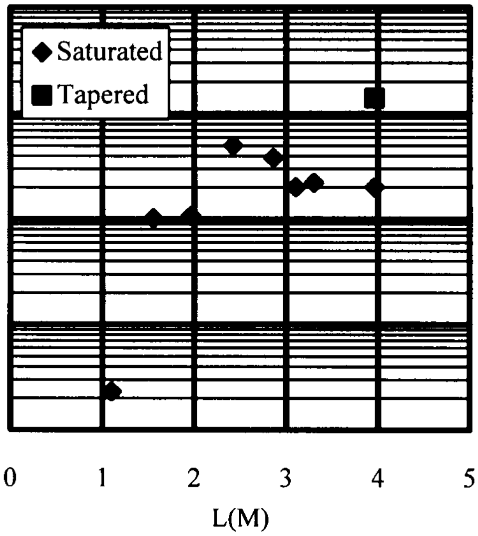

Fig.2 FEL Gain curve

From the experiment results we can find that only a half of the beam current has been input into the wiggler,and the pulse width becomes narrower(40ns),for the corkscrew motion of the beam due to the energy spread and the misalignment of the magnetic axis results in the different displacements at different time of the pulse. The wave guide actually behaved as selector of both emittance and position. This maybe the main reason of the reduced beam current widths. The beam energy in the head and tail of the pulse is lower than that in the middle , in order to let those in the middle with small energy spread have small displacements so that those electrons can entrance the wave guide through the space and energy sweep selector,the magnetic field of conditioning section must be carefully adjusted

## REFERENCES

[1] Pasour,J.A, Phys. Rev. Lett., Vol.53,pp.1728-1731,1984.

[2] Orzechowski,T.J. et al, Phys. Rev. Lett.,Vol.54,pp.889-892,1985.

[3] Elias,L.R.,Proc.9th Int. Conf. Infrared and Millimeter Waves,Takarazuka,Japan,Oct.22-26,1984 pp.1-3.

[4] Gold,S.H. et al,Phys.Rev.Lett..Vol.52,pp.1218-1221,1984

[5].Turner,W.C.,Proc.1990 Linac Conf.Albuquerque,NM.Sept. 10-14,1990,pp435-437.

[6].Sampayan,S.E,Proc.1990 Linac Conf. Albuquerque,NM, Sept.10-14,1990,pp417-419

[7] Hui Zhongxi,Deng Jianjun et al,Proc. First Asian Symposium on Free Electron Laser,Beijing,May 26-30,1993.