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RESEARCH POTENTIAL OF TAC IR FEL

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Abstract. - In this study, different options and applications of IR FEL in basic and applied sciences are investigated in detail. In this frame, the main parameters and research potential of Turkish Accelerator Center Infrared Free Electron Laser Facility (TAC IR FEL) are described that is a project ongoing under the coordination of Ankara University with support of State Planning Organization (SPO) of Turkey since 2006. IR FEL facility is being planned to cover MIR and FIR region as 2-185 microns wavelengths and will be completed in 2011. Properties and main characteristics of different application methods of IR FEL are examined in research field of semiconductors, material science, photochemistry, biology and nanotechnology. The structure of experimental stations and considered techniques are explained regarding well known IR FEL laboratories in the world.

1. INTRODUCTION

As a first facility of TAC, an IR FEL facility is proposed. For the third phase of TAC project after facility and CDR phases, (to complete TDR of TAC and to construct first facility), with the support of State Planning Organization (SPO), 70 scientists from 10 Turkish universities are studying within the coordination of Ankara University. First facility (IR FEL) will be constructed in Gölbaşi Campus area of Ankara University[1].

Free Electron Laser (FEL) is a laser that uses electrons which are not confined to an atomic or molecular bound state. A relativistic electron beam coming from a linac is inserted to a sinusoidal magnetic field called undulator magnet. While passing through the undulator, electron beam losses some of its energy and emits radiation. The radiation emitted from the beam is trapped between two mirrors. When the radiation power is saturated, it is taken out of one of the mirrors via a hole [2].

The FEL is a important tool for scientific applications requiring tunable coherent radiation in the infrared and UV ranges. Although there are numerous conventional lasers, FELs have some advantages :Tunable and coherent light, short pulse structure, high peak power and average power, high flux and brightness [3].

2. General Application Potential of IR FEL

Some applications of IR FEL can be given respectively; material science, semiconductors, photochemistry, protein dynamics, nonlinear optics, radiochemistry, photon science, biotechnological research, medical applications by using different techniques; infrared spectroscopy and microscopy, infrared imaging, elipsometry, THz spectroscopy, photo-thermal and photo-acoustic spectroscopy, sum frequency spectroscopy, near field optical microscopy, pumb-prob measurements, multi photon ionization, vibrational and rotational spectroscopy.

3. TAC IR FEL Facility

TAC IR-FEL facility will contain an electron linac in 15-40 MeV energy range and two optical resonators. These optical resonators have same lengths but different two undulators with 3 cm and 9 cm periods. A coherent radiation will be obtained in 2-185 microns range. Main parameters of TAC IR FEL is given in Table 1[4].

Table 1: Main Parameters of TAC IR FEL

Parameter	**FEL-1**	**FEL-2**
Wavelength (μm)	2.7-30	10-190
Pulse energy @80 pC[μJ]	2	4
Pulse energy @120 pC[μJ]	4	10
Max peak Pow @80 pC [MW]	8	10
Max peak Pow @120 pC [MW]	12	15
Pulse length (ps)	1-10	1-10

4. Research Potential of TAC IR FEL Facility

The main goal of the TAC IR FEL facility is to make new researches in different scientific research in basic and applied research in Turkey and region. Considering the advantages of FEL, we propose to use IR FEL in following research areas at 8 experimental stations[5]:

- Photon science
- Material science
- Semiconductors
- Biotechnological and medical research
- Non-linear optics
- Nanotechnology
- Photo-chemistry

The laser beams from the two undulators having wavelength between 2-185 μm, will be transported to eight experimental stations with a beam transport optical systems composed of vacuum beam ducts and mirror systems. One of these stations will be diagnostic room for FEL beams. As an initial process, the quality of the laser beam will be examined such as the time structure, intensity, spectroscopic bandwidth and other properties of the FEL and then transported to each experimental room.

The second room will be occupied for general IR FEL spectroscopy, FT-IR spectroscopy, raman spectroscopy. Laser spectroscopy in the IR is, as yet, largely based on molecular gas lasers that operate at fixed frequencies [6]. With the development of the FEL a pulsed source of intense and coherent radiation has become available that is, in principle, tunable over a wide spectral range and should offer sample opportunities for spectroscopy in the IR region. Identification of all types of organic and many types of inorganic compounds, determination of functional groups in organic materials, determination of the molecular composition of surfaces, quantitative determination of compounds in mixtures, determination of molecular conformation and stereochemistry, determination of molecular orientation are some of the applications fields for our second experimental station.

In the third experimental station, some of spectroscopy techniques in IR region will be used for investigation of material sciences and semiconductors by using the sum frequency generation and pump- probe techniques. The fingerprint region is important for these techniques. The TAC IR FEL is provided the necessary tunability wavelength range, high power during short pulse duration.

Visible-infrared sum frequency generation (SFG) is a nonlinear optical technique capable of generating vibrational spectra. Chemical species can be identified and molecular orientation and molecular surface density can be measured with this technique [7]. Using the extremely wide tunability and the high peak power of a FEL it can be studied the frequency dependence of the nonlinear susceptibility for sum-frequency generation [8].

Surface science experiments would use several unique properties of FEL radiation. Continuously tunable high-intensity radiation, which would allow probing of specific vibrational frequencies with good signal-to-noise ratio and picosecond pulses, which would allow pump-probe techniques to be used to study energy transfer processes at the surface. Picosecond infrared free electron lasers have been used to perform time-resolved pump-probe spectroscopy in the mid infrared. By using time-resolved pump-probe techniques it will be possible to investigate the temporal evolution of a variety of processes, like electronic relaxation of autoionization states, coupling between two autoionization states, coupling between electronic and nuclear motion in molecular systems, fast dissociation of molecules upon inner- and outer-shell photoexcitation, coherent population of fragment states etc [9].

The other five stations will be planned to carry out the non-linear optics, nanotechnology, photochemistry and biotechnology, research.

5. Conclusion

TAC IR FEL facility will give some opportunities to scientists from Turkey and in region, to enhance and foster their basic and applied research in different fields by using new generation light source. The spin off by dissemination of knowledge and the performance of experienced man-power will provide the substantially increased level of recognition of project in the region. It is acknowledged, the outstanding success of this project will be reflected and resulted as an initialization another new accelerator based facilities such as synchrotron radiation and SASE FEL.

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