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INTRODUCTION OF THE LASER INTENSITY MEASUREMENT SYSTEM FOR THE FELiChEM*

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Abstract

The FELiChEM is a new infrared free electron laser (IR-FEL) facility, which is being built in the National Synchrotron Radiation Laboratory (NSRL) in Heifei, China. The facility will provide continuously tunable pulsed laser radiation covering the mid-infrared (MIR) wavelength range from 2.5 to 50μm and the far-infrared (FIR) range from 40 to 200μm. The output macro pulsed laser width is 5-10μs and pulsed laser power is 2-10kW. In order to evaluate pulsed laser saturation time and FEL optical cavity losses, the rise time and fall time of macro pulsed laser need to be measured. Laser intensity measurement system for the FELiChEM is being designed. This system is composed of optical system, pyroelectric detector and electronics. Each module will be described in detail in this paper. The laser intensity measurement system was tested under offline and online conditions. The results showed that pulsed laser of 10μs width can be measured and the design requirement can be met with this system.

INTRODUCTION

FELiChEM is a new experimental facility that can generate mid-infrared and far-infrared laser. The laser parameters for the FELiChEM are shown in Table 1 [1]. According to these parameters, the calculated power of the macro-pulse and average power are 2-10kW and 2W respectively. In order to evaluate pulsed laser saturation time and FEL optical cavity losses, a laser intensity measurement system is being designed to evaluate the laser parameters and speed up the machine commissioning for the FELiChEM facility.

Table 1: The Laser Parameters of the FELiChEM

Parameter	Specification
Spectral range	2.5-50μm (MIR) 40-200μm (FIR)
Bandwidth	0.3%-3%
Macro-pulse energy	10-100mJ
Macro-pulse length	5-10μs
Repetition of macro-pulse	20Hz
Micro-pulse energy	5-100μJ
Micro-pulse length	1-5ps

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THE LASER INTENSITY MEASUREMENT SYSTEM

The layout of the laser intensity measurement system for the FELiChEM facility is shown in the Fig. 1. The infrared pulse laser coupled out from the optical cavity reaches the laser intensity measurement system through a nitrogen-filled pipe, which can reduce the absorption of the infrared laser by the air.

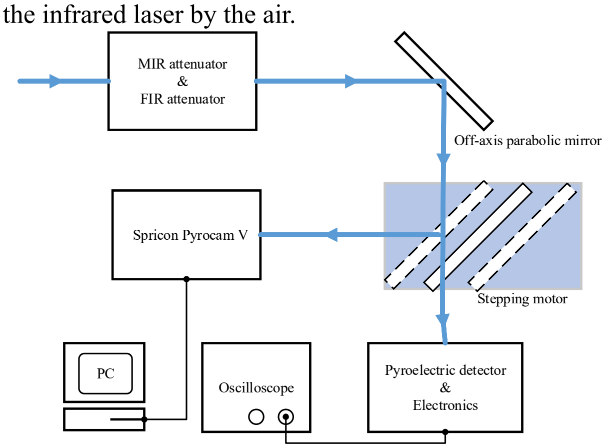

Figure 1: Layout of the laser intensity measurement system.

Due to the high average power of the macro-pulse of the FEL, the laser needs to be attenuated by the attenuator to protect the detector. Then laser is focused by an off-axis parabolic mirror and absorbed by the detector. Since laser profile also need to be monitored, an infrared camera named Spricon Pyrocam V was also placed on the optical platform. The off-axis parabolic mirror will be controlled by a stepping motor to transfer the FEL laser to the pyroelectric detector or the pyroelectric camera. As the topic of this paper is to introduce the laser intensity measurement system, so laser profile measurement will not be introduced. The main composition for this system will be presented in the following.

Pyroelectric Detector and Electronics

Pyroelectric detector is a detector that converts radiation pulsed light into electrical signal by the pyroelectric effect [2]. Compared to cryogenic detectors, the pyroelectric detector can work at the room temperature and a wider response range. It has a lower cost, but a lower detectivity and responsibility.

The output signal for the pyroelectric detector is proportional to the temperature characteristics of the pyroelectric material and the area of the detector. The pyroelectric detector used in the laser intensity measurement system is

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manufactured by Gentec-EO (QS5-IF) [3]. The detector's characteristic parameters are listed in Table 2.

Table 2: Characteristic Parameters of the Detector

Specifications	Values
Spectral range	0.1-1000μm
Max average power	50mW
Effective aperture	Φ 5mm
Noise equivalent pow-er(@630nm,15Hz)	1.6E-7 $W/(Hz)^{1/2}$
Detectivity(@630nm,15Hz)	2.8E8 $cm(Hz)^{1/2}/w$
Current responsivity(I, Theo-retical value)	0.25μA/W
FeedBack resistor (R_f)	100MΩ

The current responsivity in Table 2 is the theoretical value. The current responsivity of different detectors will be different, which can be obtained by calibration. The equivalent circuit of the detector used in the measurement system is shown in Fig. 2.

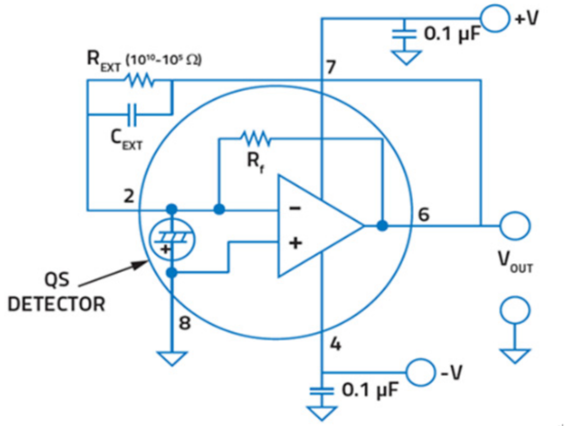

Figure 2: The equivalent circuit of the detector.

According to the data in Table 2 and the equivalent circuit in Fig.2, the output signal for the pyroelectric detector can be expressed as:

$$V_{out} = (R_{EXT} // R_f) \cdot I \cdot P_{FEL} = V_R \cdot P_{FEL} \quad (1)$$

In the Equation 1, V_{out} is the output voltage amplitude and V_R is the voltage responsivity. R_{EXT} is the external resistor, which can be used to adjust response time and bandwidth of the electronics. The value of R_{EXT} is 100 KΩ, which is suitable for the measurement system. The calculation results show that the voltage responsivity of the measurement system is 25 mV/W and the rise time is 44 ns, which can meet the measurement requirements for the power and width of the FEL macro-pulse.

Attenuators

Table 2 shows that the maximum average power measured by the detector (Damage threshold) is 50mW, while the average power of the macro pulse for the FELiChEM facility is about 2W, so attenuator is required to attenuate the laser power. In the measurement system, MIR and FIR attenuators are used, which are Model 102 produced by LASNIX and ATS5-50.8 manufactured by TYDEX. Model 102 covers mid infrared wavelength range between 2.5μm - 36μm and has five attenuators, whose attenuation in decibels are 3dB, 5dB, 8dB, 9dB and 10dB repectively. ATS5-50.8 covers far infrared wavelength range between 40μm - 1000μm and have four attenuators, whose transmission are the 30%, 10%, 3%, and 1% respectively.

TEST RESULTS OF THE MEASUREMENT SYSTEM

Three laser sources including HeNe laser, semiconductor laser and CTFEL facility were used to perform off-line and on-line tests for the laser intensity measurement system. Under these offline and online tests, different REXT resistance values were chosen.

Test Result with HeNe Laser

The HNL008L HeNe Laser manufactured by Thorlabs was used, whose output was a constant red light with a wavelength of 632.8 nm and a DC power of 0.8 mW. The light source was modulated with a chopper to output a pulsed power of 0.8 mW. Because of the low laser power, high-resistance R_{EXT} (100 MΩ) was chosen to ensure high voltage responsivity. The measurement result is shown in Fig. 3. The peak-to-peak value of the pulsed signal is 31.8mV. The rising edge of is 105.8μs and the width is 500.2μs.

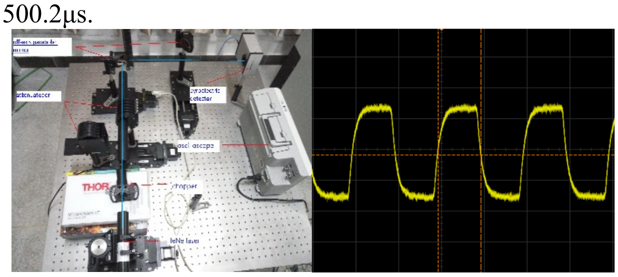

Figure 3: The test platform (left) and measurement results (right).

Test Result with HeNe Laser

Figure 4 shows the layout of the test platform with the semiconductor laser and the measurement result. The semiconductor laser outputs a laser with a wavelength of 808nm, the pulse width of this laser is 10μs and the peak power is 1W and the value of the R_{EXT} is 1 MΩ.

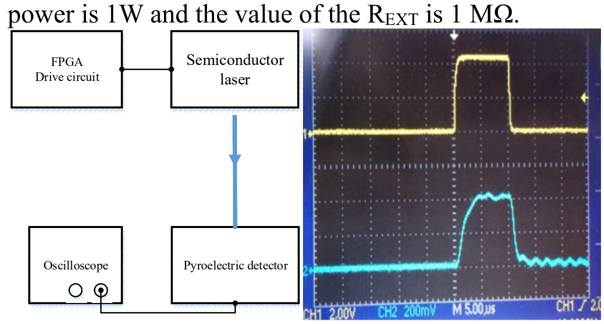

Figure 4: Layout of the test platform (left) and the measurement result (right).

In the measurement results in Fig. 4, the yellow pulse signal is used as a trigger signal of the semiconductor pulse laser, the pulse width is 10μs, and the repetition

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frequency is 20 Hz. The blue one is the output signal measured by the detector, whose peak-to-peak value is about 400 mV, the signal rising edge is 3μs, and the falling edge is about 1.5μs.

Test on CAEP THZ-FEL Facility

CTFEL facility is cited in the Institute of Applied Electronics of China Academy of Engineering Physics (CAEP). For this facility, a cryogenic GeGa detector was used to measure laser macro-pulse waveform and saturated lasing signal was firstly observed on Aug. 29. It is a great honor to test our pyroelectric detector on the CTFEL facility [4]. The signals obtained by the pyroelectric detector and the GeGa detector are consistent.

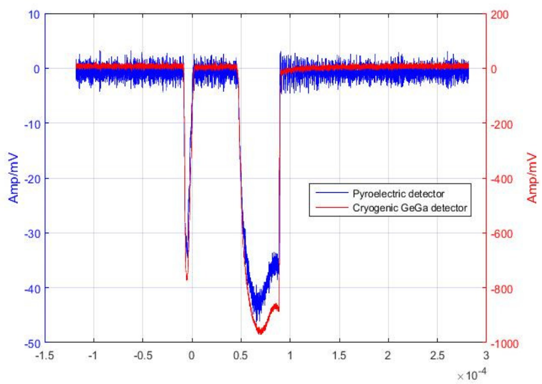

Figure 5: The test results of the two detectors.

The amplitude of the red signal in Fig. 5 is 925.9 mV, which is obtained from the cryogenic GeGa detector. The blue one is obtained by our pyroelectric detector (the value of the R_{EXT} is 100 KΩ) and its amplitude is 16.6 mV. The difference in signal amplitude is due to the higher voltage responsibility of cryogenic GeGa detector. The output pulse waveforms of both detectors are the same and the pulse width is 36.8us.

SUMMARY

The laser intensity measurement system for the FELiChEM are introduced in detail. The detector and electronics were tested under three offline and online conditions. For different power lasers, REXT can be adjusted to meet the voltage responsivity and time response requirements. These results show that the laser intensity measurement system can measure a pulsed laser with a width of 10us, which can meet the measurement requirement.

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