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ALIGNMENT AND INSTALLATION FOR THE FELICHEM PROJECT*

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Abstract

FELiChEM is a new experimental facility under construction at the University of Science and Technology of China. There are more than one hundred important devices to construct it, which core device is two free electron laser oscillators generating middle-infrared and far-infrared laser and covering the spectral range of 25-200μm. The optical cavity is an important component of oscillator which very sensitive to misalignment errors of the mirror, due to its near-concentric and symmetric structure. High precision alignment and installation is necessary to ensure the smooth implementation of the FELiChEM project. Laser tracker and Level are used to install this devices according to the alignment control network. An efficient and high-precision alignment method based on autocollimator and photoelectric auto-collimator is used to align optical cavity of oscillator. This methods is proven to be effective and meet the tolerances by multiple means.

INTRODUCTION

A free electron laser (FEL) is a device that transforms the kinetic energy of a relativistic electron beam into electromagnetic (EM) radiation when the electron beam goes through a periodically alternating magnetic field. It can provide coherent radiation in any part of the electromagnetic spectrum. Even more, the wavelength can be continuously tuned, the intensity can be very high, and the pulse length can be very short. These attributes make the FEL extremely attractive as a coherent radiation source [1].

In 2014, a project of infrared laser for fundamental energy chemistry, named FELiChEM, was approved under the financial support of the Natural Science Foundation of China, and an infrared FEL began to be built in Hefei. The National Synchrotron Radiation Laboratory (NSRL) of USTC is responsible for the design, construction and commissioning of the IR-FEL apparatus. It will be a dedicated experimental facility aiming at energy chemistry research. Its core device is a free electron laser generating 2.5-200μm laser for photo excitation, photo dissociation and photo detection experimental stations. Two oscillators driven by one RF Linac will be used to generate mid-infrared (MIR) (2.5-50μm) and far-infrared (FIR) (40-200μm) lasers. The IR-FEL facility will be placed in a 16m×10m×3.2m hall with 2.8 meters-thick shield walls. As shown in Fig. 1, the IR-FEL is composed of two FEL oscillators driven by one electron Linac. Two accelerating tubes (A1, A2) are used to accelerate the electron beam to the maximum energy of 60MeV. Between the first and the second accelerating tube, a four-dipole magnetic chicane is designed as an optional operation condition. The optical cavity is one of the major components of an FEL system. In this case, it consists of two gold-coated copper spherical mirrors facing each other. The two mirrors have a diameter of 50mm. The downstream mirror has a 3.5-mm-diameter hole for power out-coupling [2-4].

This paper will sketchily introduce the overall process of alignment and installation of the FELiChEM project. Laser tracker (LEICA AT960, LTD840+NIVEL20) and Level are used to install this devices according to the alignment control network and an efficient and high-precision alignment method based on autocollimator and photoelectric auto-collimator is used to align optical cavity.

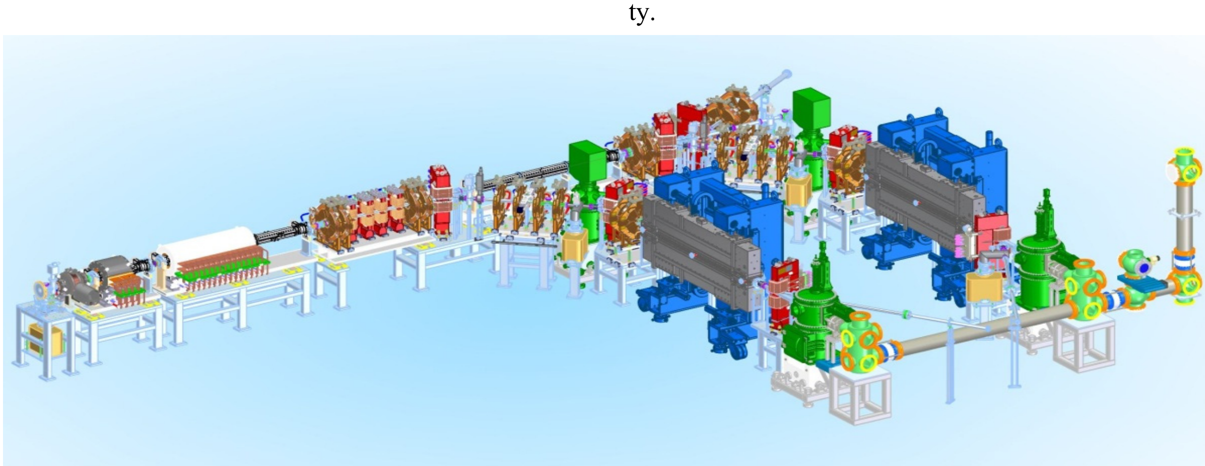

Figure 1: Overview of the FELiChEM.

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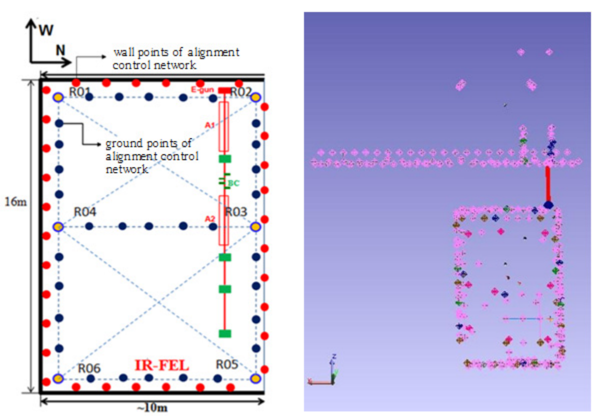
DESIGN AND LAYOUT OF ALIGNMENT CONTROL NETWORK

Because of the relatively independent of the experimental hall, the control network is also relatively independent. The control network design and layout will refer to the actual layout of the experimental hall. The most of FELiChEM components will be located in a 16m×10m×3.2m hall and are separated with the light beam with 2.8 meters-thick shield walls [5-7]. Two embedded pipes are buried into shield wall to ensure intervisibility. There are totally 11 laser tracker measurement stations to measure the all control network points, and there are at least six common points each other. USMN (United Space Metrology Network) of SA software is used to process the multiple stations, as shown in Fig. 2. USMN can optimizes the complex multi-station measurement network to solve for the best station and target locations. Its produces the best point coordinates from the measurements [8-9].

According to the USMN report, the RMS of points error is 0.0175mm and the worst point error is 0.0957mm at XQ08 point, which point is located in the west wall. It is proven that the stability of wall points is not as good as ground points.



Design of the control network The actual control network

Figure 2: The design and measurement of control network.

PRE-ALIGNMENT AND ALIGNMENT OF FELICHEM PROJECT

The pre-alignment data of the most devices, such as dipole and quadrupole magnets, are provided by the manufacturers. We just check the data by random inspection. The electronic gun, focusing coil and accelerator tubes is pre-aligned by T-probe and laser tracker. We use the laser tracker to align this devices according to the alignment control network as described above [10-11]. The accuracy requirement of different devices as shown in Table 1. The digital level is used to ensure the all devices are adjusted at the same level. As shown in Fig. 3.

Otherwise, the core device that two free electron laser oscillators are aligned by an efficient and high-precision alignment method based on autocollimator and photoelectric auto-collimator. The laser oscillator consists of two gold-coated copper spherical mirrors facing each other into two vacuum stainless steel drums. A 10mm width vacuum chamber is used to connect the two vacuum stainless steel drums and there are three POP-IN sensors are installed into vacuum chamber to detect the beam energy [12-13].

According to the simulation result carried out by using GENESIS and OPC code, the tilt angle should be less than 0.05mrad for both mirrors to obtain the optimum FEL output power.

Figure 3: The pre-alignment and alignment of components.

Table 1: Accuracy Requirements for Different Devices

Name of magnet	Tolerance of magnet ΔX (mm)	ΔY (mm)	ΔZ (mm)	Δθx (mrad)	Δθy (mrad)	Δθz (mrad)
Dipole and Switch magnet	0.15	0.15	0.1	0.1	0.1	0.1
Quadrapole and Correct magnet	0.15	0.1	0.1	0.2	0.2	0.15
Accelerator tube	0.15	0.1	0.1	0.3	0.2	0.2
Undulator	0.15	0.1	0.1	0.1	0.1	0.1

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In order to prove the high-precision alignment, we prepare three different methods based on autocollimator and photoelectric auto-collimator as shown in Fig. 4. All three methods were adopted to align these mirrors and we check the alignment results each other [14].

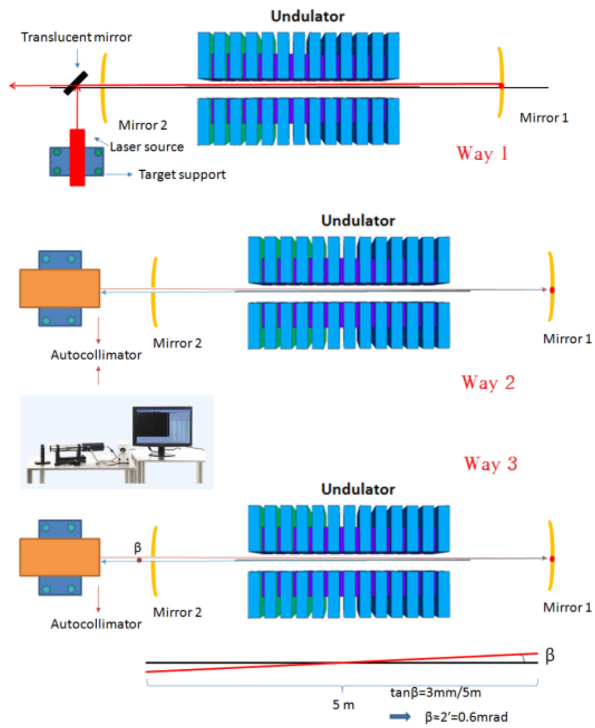

Figure 4: The three different methods for oscillators alignment.

Afterwards, Autocollimator method is proven more suitable to align the two mirrors.

The same alignment method is also adopted to align the six POP-IN sensors, as shown in Fig. 5. because of there is less light into the vacuum chamber, we need add a light source to improve the vision field. The holes of three POP-IN sensor are adjusted to nearly concentric[15-16].

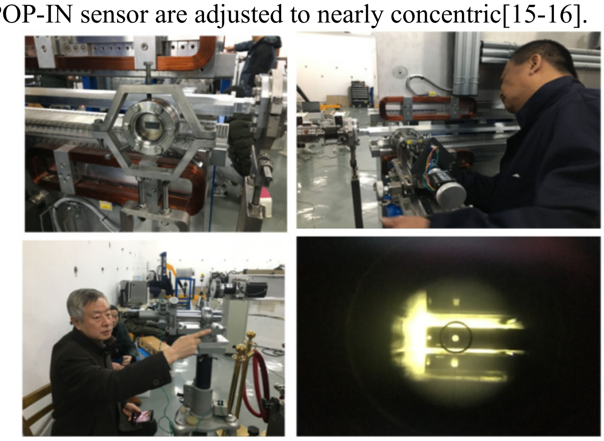

Figure 5: Alignment of POP-IN by the autocollimator.

CONCLUSION

In this paper, we outline described the alignment process of FELiChEM project. By employing the laser tracker and Level, most of components are aligned and installed in the correct location. Otherwise, a new concept for oscillators alignment based on autocollimator has been presented and the mirror was placed in the correct location with the correct orientation. The facility is under construction, and the first light of FELiChEM is targeted for the Aug. 2018.

REFERENCES

[1] W. WANG and X. Y. He, "The surveying data processing of control network based on HLS upgrade", in *Proc. 4st Int. Particle Accelerator Conf. (IPAC'13)*, Shanghai, China, May 2013, paper WEPME025, pp. 2986-2988.

[2] X. LIU *et al.*, "Optical alignment and tuning system for the HUST THz-FEL", *Nuclear Instruments and Methods in Physics Research A.*, vol. 43, pp. 931-934, Feb. 2016.

[3] L.Y. Tian and J.P. Yue, "Engineer control surveying", *Wuhang University Press*, Wuhang, China: , 2011, pp. 19-24.

[4] X.Y. He *et al.*, "Measurement and adjustment of control network of NSRL storage ring", *Nuclear Techniques.*, vol. 32, pp. 813-817, 2009.

[5] J. G. Yoon and S. G. Li, "Smoothing analysis of PLS storage ring magnet alignment", in *Proc. 1st International Workshop on Accelerator Alignment*, SLAC, American, May 1989, pp. 101-105.

[6] D. J. Dunning and N. R. Thompson, "Overview and status of the ALICE IR-FEL", in *Proc. 10st International Workshop on Accelerator Alignment*, Liverpool, UK, May 2009, pp. 583-586.

[7] F. Barry and B. Tom, "Surveying principles and application Ninth edition", Springer, New York, American, 2011, pp. 121-124.

[8] J. P. Qusnel, "The first positioning of the LHC cryo-magnet", LHC-G-ES-0029, November. 2001.

[9] C. Poedvin, "The smoothing of the cryo-magnet", LHC-G-ES-0010, December. 2001.

[10] N. Woodhouse, "Plane, a tool for smoothing accelerators", internal note, October. 1995.

[11] D. Missiaen *et al.*, "The alignment of the LHC", in *Proc. 2st Int. Particle Accelerator Conf. (IPAC'09)*, Vancouver, Canada, May 2009, paper WE4GRC04, pp. 1973-1975.

[12] W. Wang *et al.*, "Smoothing analysis of HLS II storage ring magnets", *Chinese Physics C*, vol. 40, p. 127001, Dec. 2017.

[13] C. F. Ma *et al.*, "Modern numerical calculation method", *Science Press*, Beijing, China, 2008, pp. 79-86.

[14] G. Y. Li *et al.*, "The Principles and Applications of industrial measuring systems", Geodesy Press, California, American, 2011, pp. 176-183.

[15] H. T. Li *et al.*, "Status of FELICHEM, A new IR-FEL in China", in *Proc. 9st Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, paper THPMR022, pp. 744-746.

[16] H. T. Li *et al.*, "Design of the mid-infrared FEL oscillator in China", in *Proc. 9st Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, paper THPMR022, pp. 427-429.