IPAC21

LASER TRANSPORT SYSTEM OF SHANGHAI LASER ELECTRON GAMMA SOURCE (SLEGS)

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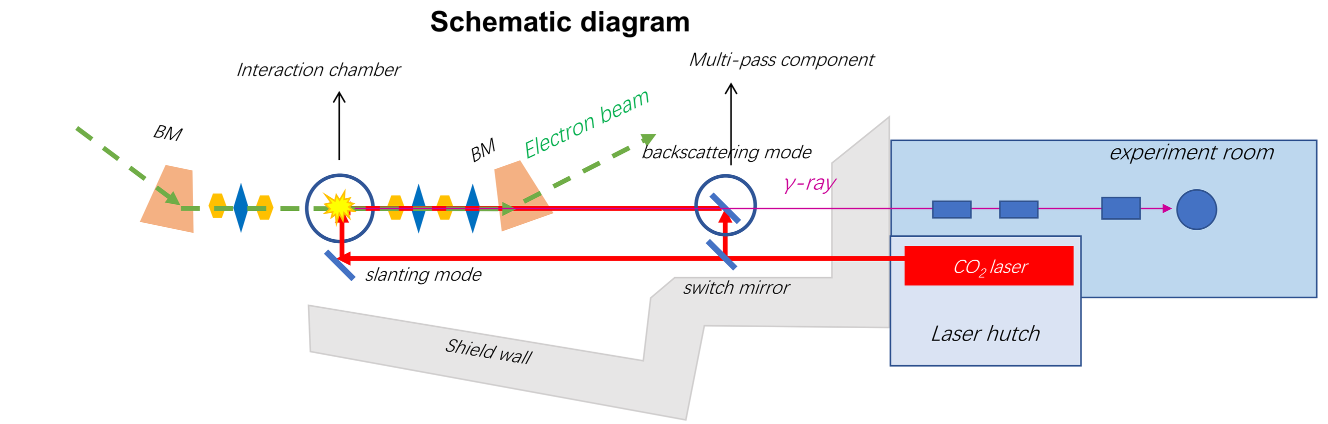
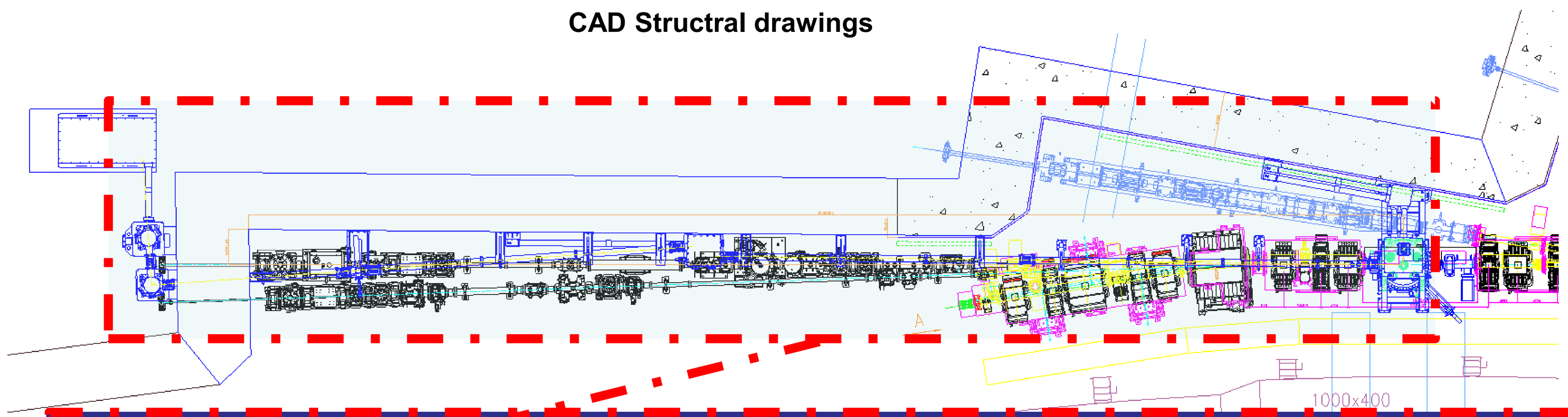
Shanghai Laser Electron Gamma Source (SLEGS) , based on Laser-Compton Scattering (LCS), as one of beamlines of Shanghai Synchrotron Radiation Facility (SSRF) in phase II, is under construction now. In order to inject the 10640 nm CO2 laser into the interaction point from the laser hutch outside the storage ring's shielding, a laser transport system longer than 20 m using relay-imaging telescopes is designed. There are two operation mode in SLEGS. One is backscattering mode, which will make the laser and electron bunch collide at 180° with flux higher than 10^7 γ/s. The other mode is slanting mode, which mainly inherits the design used in the prototype. The system contains several components to perform laser beam combining, expansion, monitoring and real-time adjustment. The polarization parameters of laser can also be measured. The design models, simulation study of the laser quality after the transportation, and the individual test experimental results of key components are presented

The overall layout

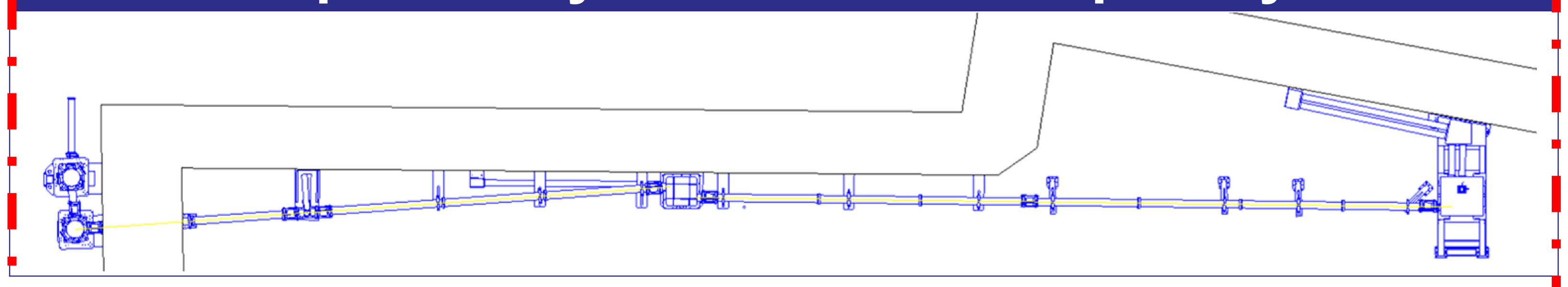
Schematic diagram



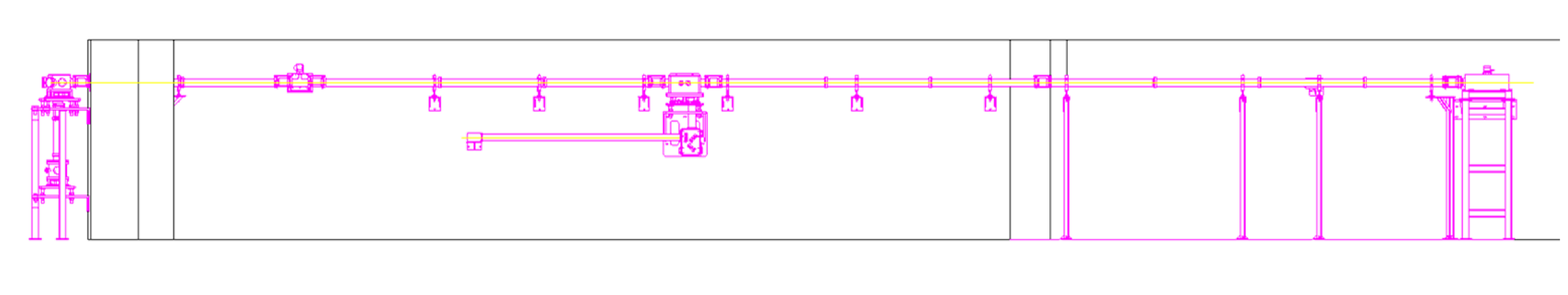
CAD Structral drawings



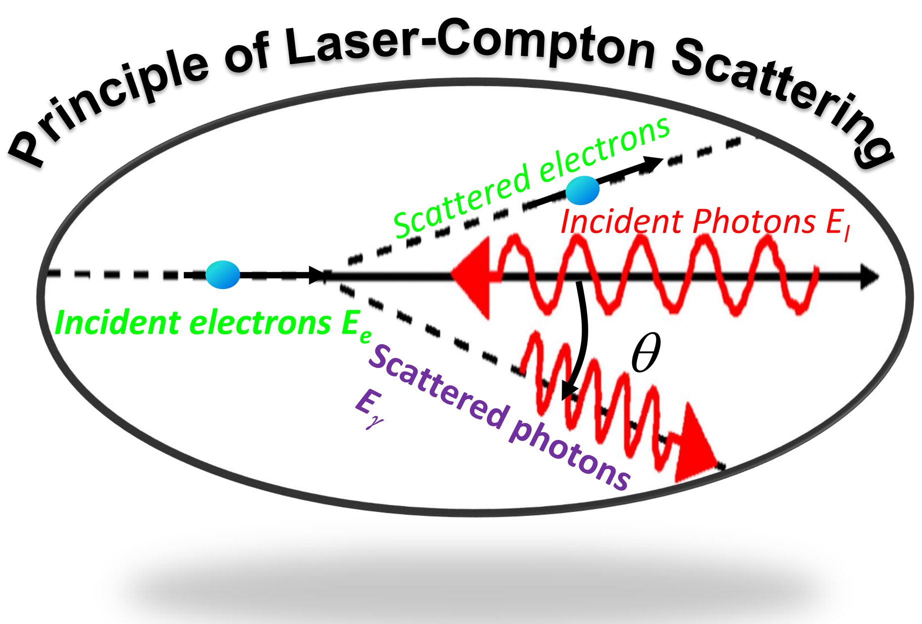
The top view layout of laser transport system



The side view layout of laser transport system



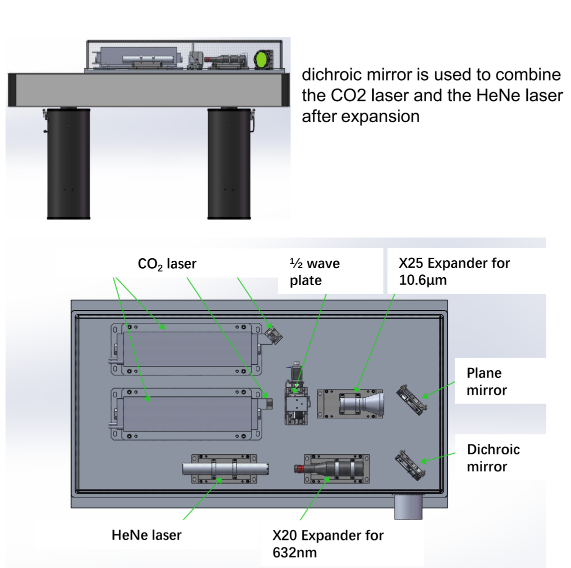
The basic characteristics of electron, laser beam, LCS X-ray		
Electron Parameters in the short straight section		
Electron energy(MeV)		3500
Energy spread(%)		0.111
Natural emittance(nm·rad)		3.48
Bunch length(rms)(σ_{le}) (mm)		4
RMS beamsize(σ_{we}/σ_{he}) (μm)		296.6/13.26
CO_2 laser		
Laser wavelength(nm)		10640
Power (CW mode) (W)		137
RMS beamsize(σ_{wp}/σ_{hp}) (μm)	Slanting mode	0.06/0.06
	Backscattering mode	1.8/1.8
Incident angle(°)		20~160
Generated γ ray		
Peak energy(MeV)		0.4-20



Key modules of Laser transport system

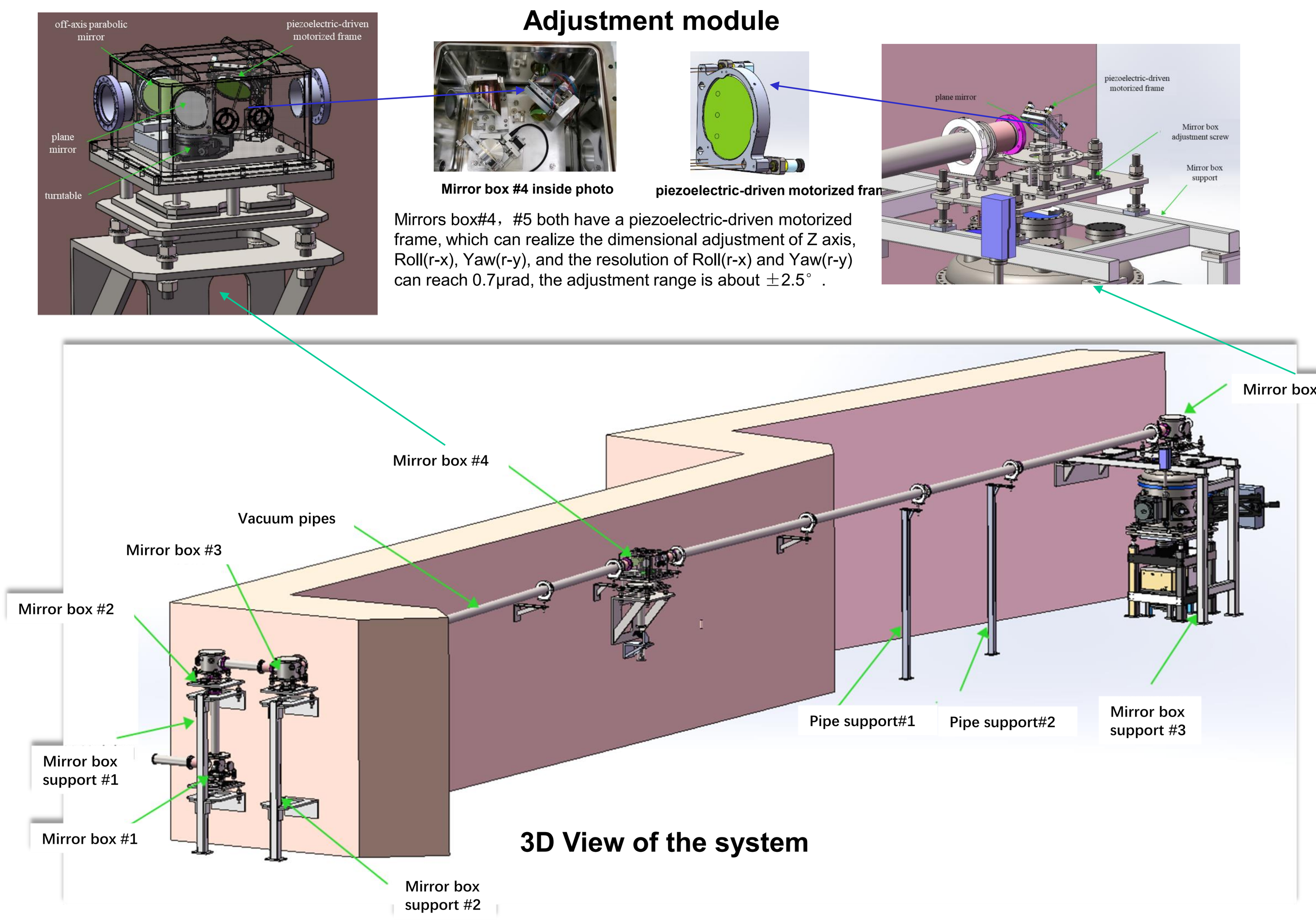
The CO2 laser and the HeNe laser for reference are transmitted together from the laser shed to the multi-pass module and the interaction chamber, and the light path turning and climbing need to be adjusted according to the on-site environment. The laser is transmitted in a low vacuum (less than 10-3 Pa) pipeline. From the laser exit to the laser interaction point, it needs to pass about 8 optical components including plane mirrors, windows and a pair of off-axis parabolic mirrors. The farthest transmission distance exceeds 23 meters.

Combination module



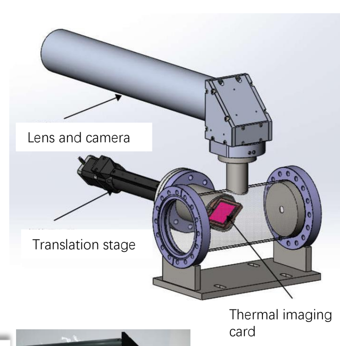
Actual photo

Adjustment module



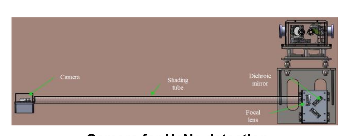
Mirrors box#4, #5 both have a piezoelectric-driven motorized frame, which can realize the dimensional adjustment of Z axis, Roll(r-x), Yaw(r-y), and the resolution of Roll(r-x) and Yaw(r-y) can reach 0.7μrad, the adjustment range is about ±2.5°.

Detection module



Coaxial detection's modal and photo

The almost-focused spot position of the two lasers is measured to judge the coaxiality of laser and He-Ne laser. Thermal detector has a spatial resolution of 20μm.

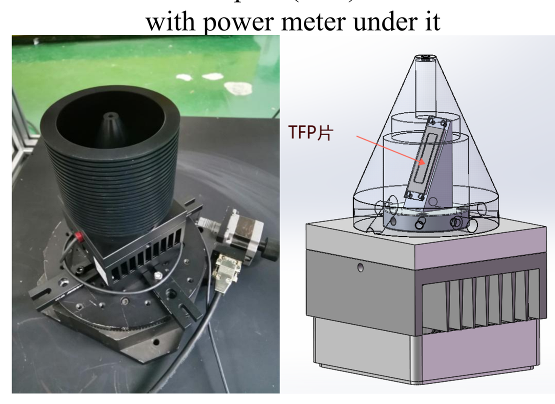


Camera for HeNe detection

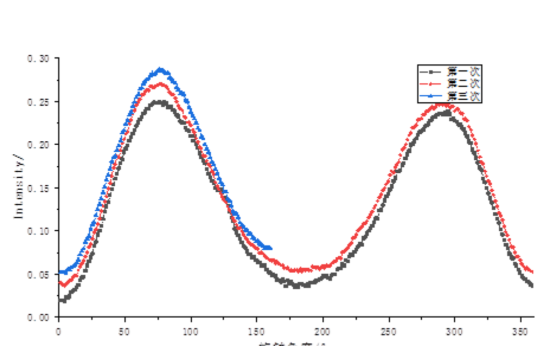
Dichroic mirror is used as splitter to reflect the He-Ne laser out of the main optical path and irradiate it to the detector through the focusing mirror with f=3m. The center peak fitting accuracy is 9μm, so the corresponding online detection accuracy is about 5μrad

Measurement of Polarization

Install the Thin film plate(TFP) on a rotatable frame with power meter under it

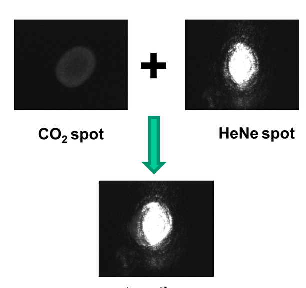


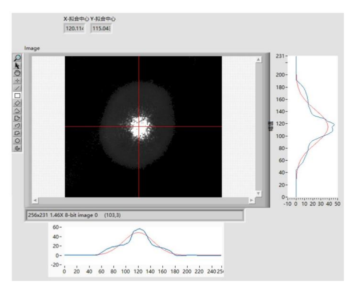
Measured results of Polarization



Measurement of Coaxiality

Images of coaxiality detection → Fitting result → The coaxiality is about 8 μrad, since the focus length of the off-axis parabolic mirror is 5.4m (41/5≈8)





No	CO2 H-center /μm	CO2 V-center/μm	He-Ne H-center/μm	He-Ne V-center/μm
1	-5.13	5.13	0.00	-20.50
2	-25.63	25.63	0.00	0.00
3	15.38	-15.38	0.00	0.00
4	15.38	-15.38	0.00	20.50
Max deviation	41.00	41.00	0.00	41.00

Study of Pointing stability after the transportation

Theoretical calculation

The pointing stability of the entire system are mainly limited by the following factors:

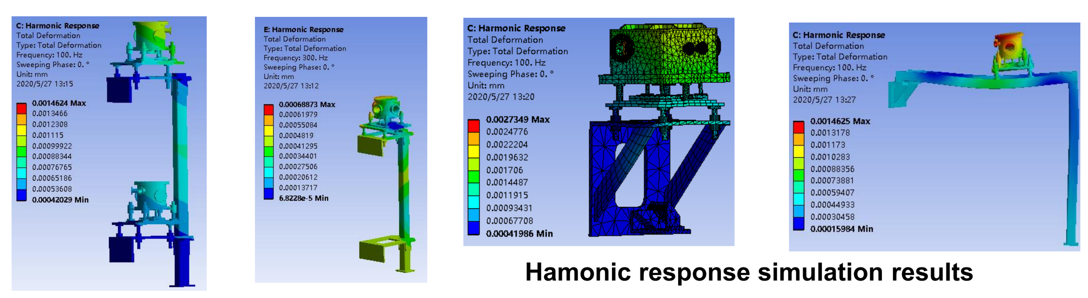
- Laser output beam's pointing stability
- System vibration
- The influence of the optical window on the light path

The angle stability of the CO2 laser is less than 250μrad, and will be reduced to 10μrad after the 25 times expansion.

According to the results of environmental vibration detection, the vibration amplitude inside the entire storage ring is within 1μm in the frequence range of 1-100Hz, typically the amplitude of the XBPM on the optical transmission system is within 0.5μm, while the XBPM height is about 1.2 meters, the corresponding angle change is 0.4μrad. The simulation shows that the eigenfrequency the support frames are nearly all larger than 100Hz.

The thickness of the ZnSe window is about 5mm. Assuming that the incident light enters the flange at an angle of 1°, then The deviation between He-Ne laser and CO2 laser is 2μm, which has little effect on the overall measurement accuracy

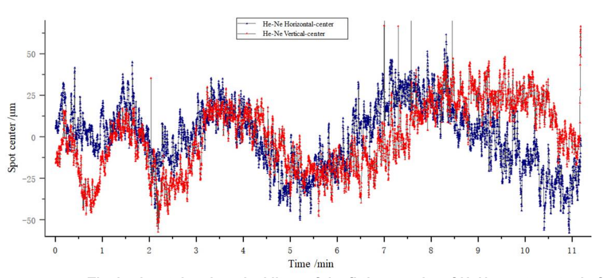
- In summary the point stability is about 10μrad and could be detected through HeNe laser.



Harmonic response simulation results

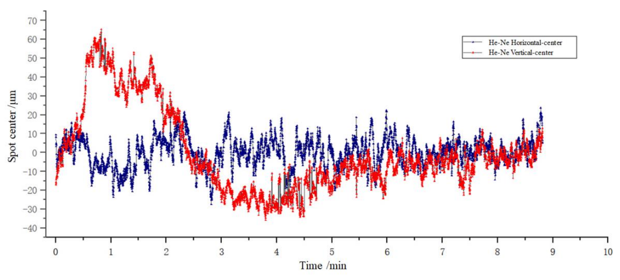
the displacement excitation of 350nm is set In the vertical direction, with 250nm in the east-west direction, and 220nm in the north-south direction. The displacement variation model under the condition of 0-100Hz is analyzed. The simulation analysis results show that the maximum deformation does not exceed 2.8μm, and the influence on the beam pointing is below 10μrad.

Experimental measurement



The horizontal and vertical jitter of the fitting results of HeNe spot center before entering multi-pass

Direction	Length RMS/um	Angle RMS/μrad
He-Ne H-deviation	19.3	6.44
He-Ne V-deviation	20.5	6.82

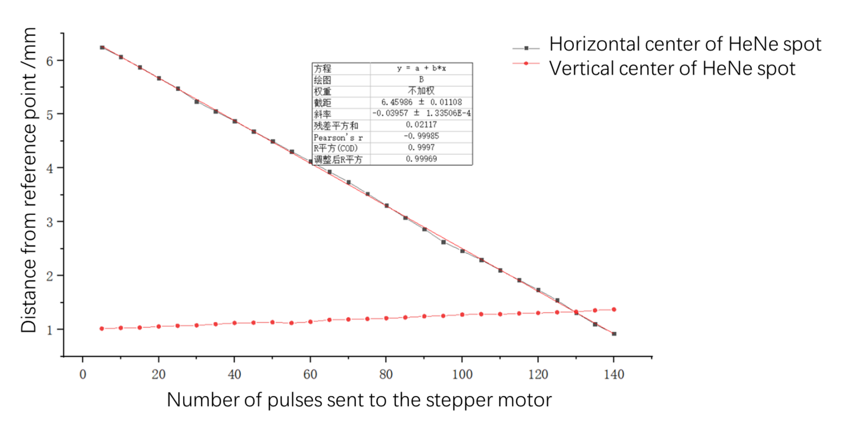


The horizontal and vertical jitter of the fitting results of HeNe spot center before entering interaction chamber

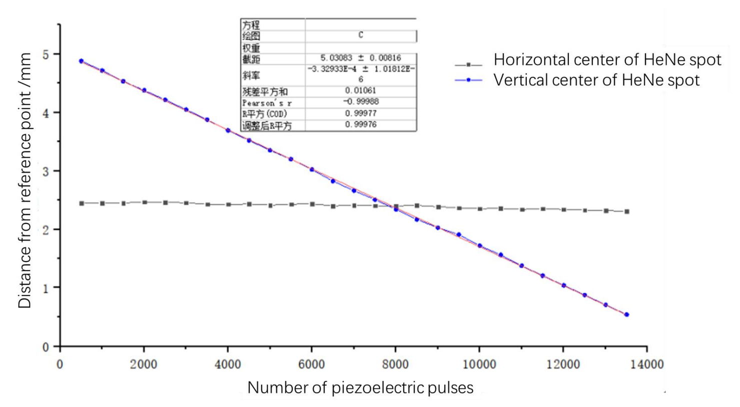
Direction	Length RMS/um	Angle RMS/μrad
He-Ne H-deviation	7.70	2.57
He-Ne V-deviation	21.6	7.19

Optimization and Correction of direction

The turntable frame in the mirror box#4 can realize the horizontal deviation of the light spot, no less than ±10mm; the turntable frame is driven by a stepping motor, and the controller is 1/200 subdivision (the highest subdivision can reach 250) and then the single pulse corresponds The deflection angle is about 0.068″, the distance between the deflection mirror and the collision point is about 11 meters, and the corresponding adjustment accuracy is about 7μm;



The precision of longitudinal translational adjustment can be realized by the simultaneous adjustment of the three piezoelectric adjustment frames in the mirror box, the longitudinal offset distance of the light spot is about 17mm; the typical single step length of the piezoelectric frame is 30nm, the stroke is 12.5mm; the piezoelectric driver is installed The spacing is 110mm, the deflection angle range>±10mrad, and the test resolution is about 1.5μrad.



Adjustment module and Detection module work together can achieve automatic scanning, which will give a map of intensity of the gamma ray at each angle. If the gamma intensity is feedback, the direction of strongest intensity can be found this way.

Once The optical path feedback system is turn on, the jitter's PV value will be reduced to 4.4/3*3≈5 μrad, make the pointing much more stable.

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SLEGS