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A novel terahertz line array detection scheme of solid-source interferometer system on EAST

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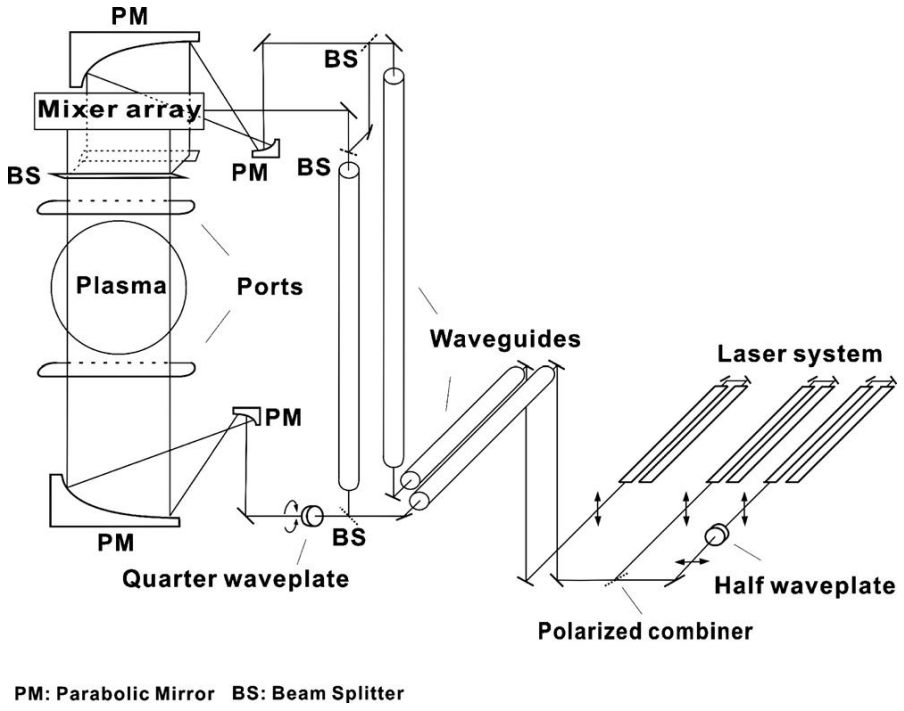
outline

1. Introduction

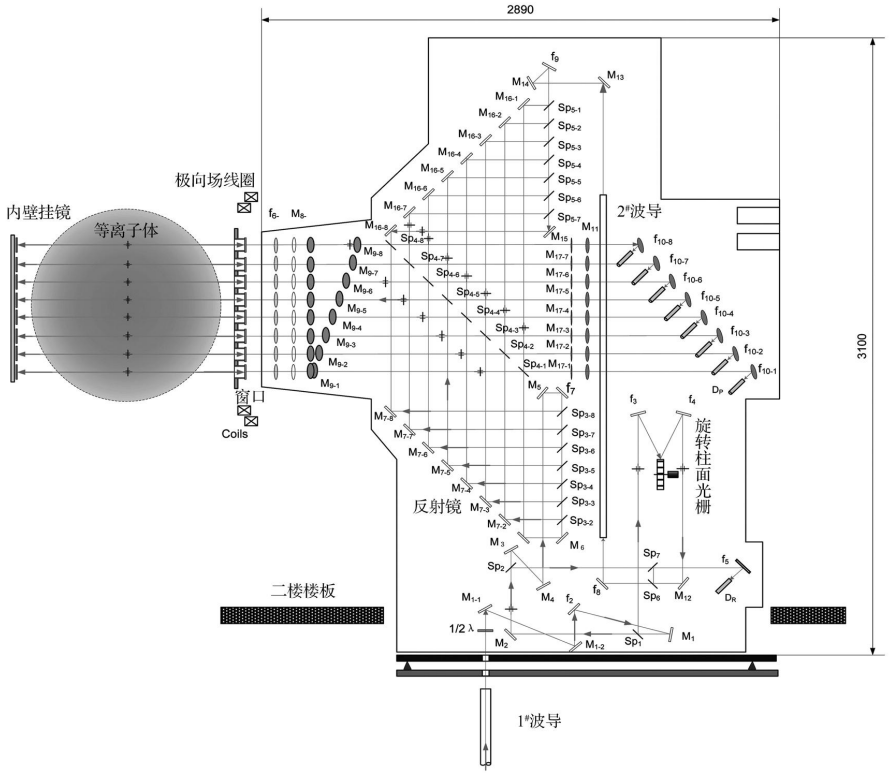
electron density diagnotics-Interferometry

- plasma **electron density** is one of the most importamt parameter on tokamak
- **Interferometry** has become a standard diagnostic means for measuring electron density profile on fusion devices.



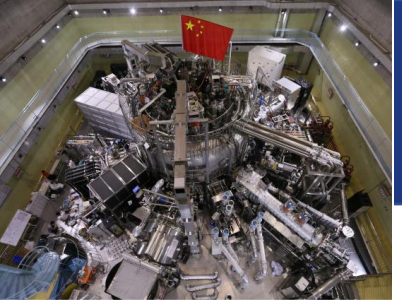
J-TEXT

continuous multi-channel detection system



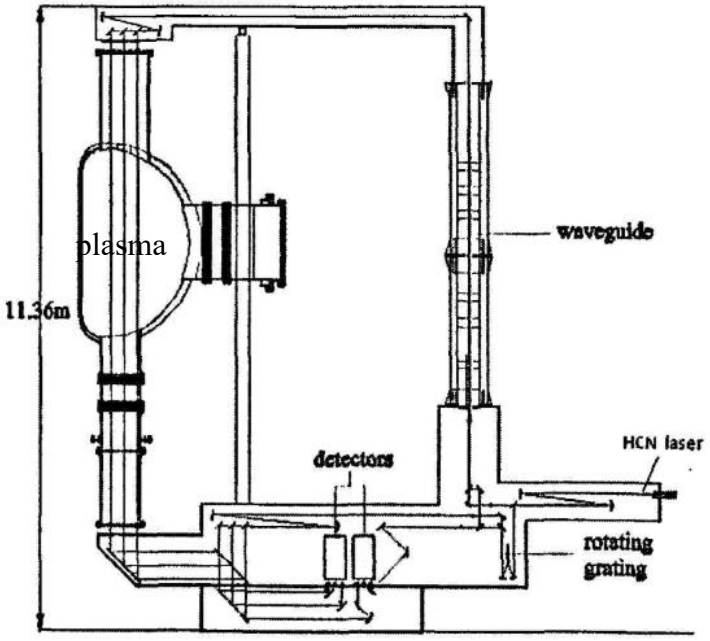
HL-2A

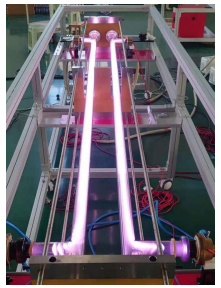
discrete multi-channel detection system



FIR interferometers on EAST

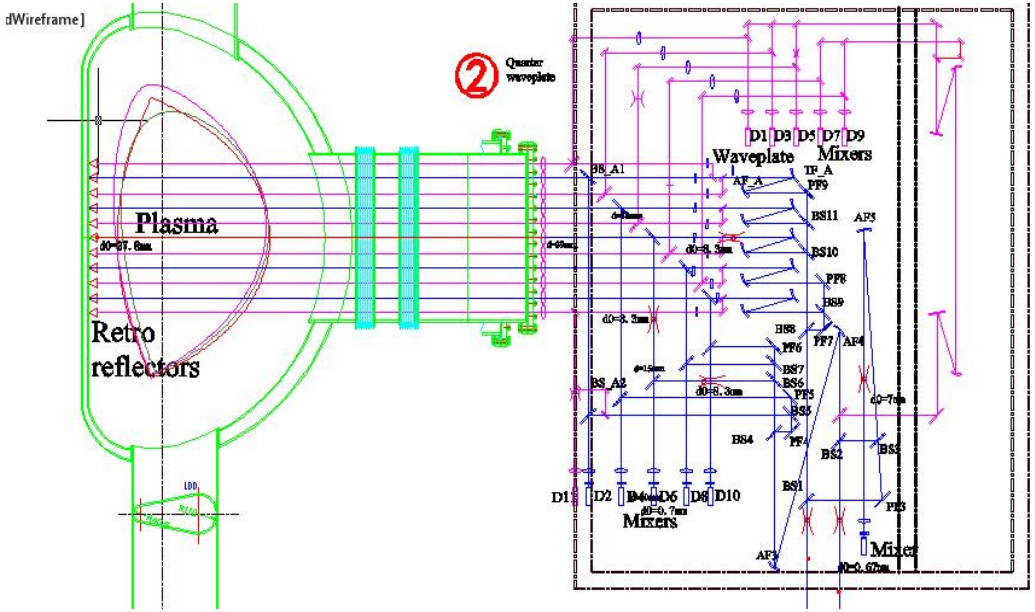
◆ HCN interferometer





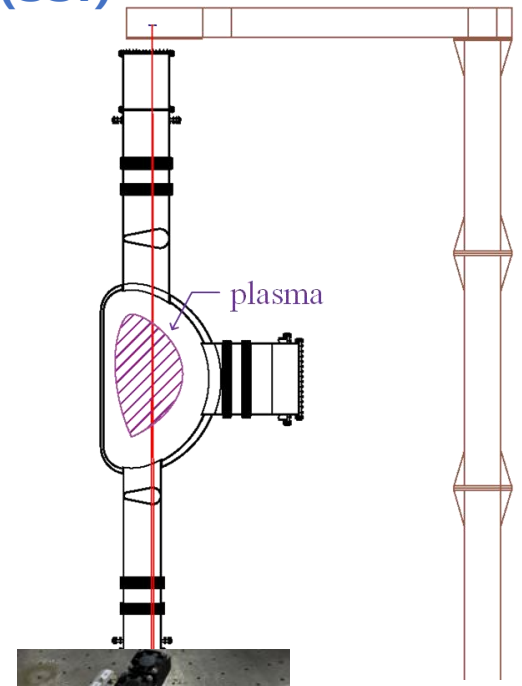
Hydrogen cyanide gas laser (HCN)
(0.89THz)

◆ Polarimeter-INTerferometer (POINT)



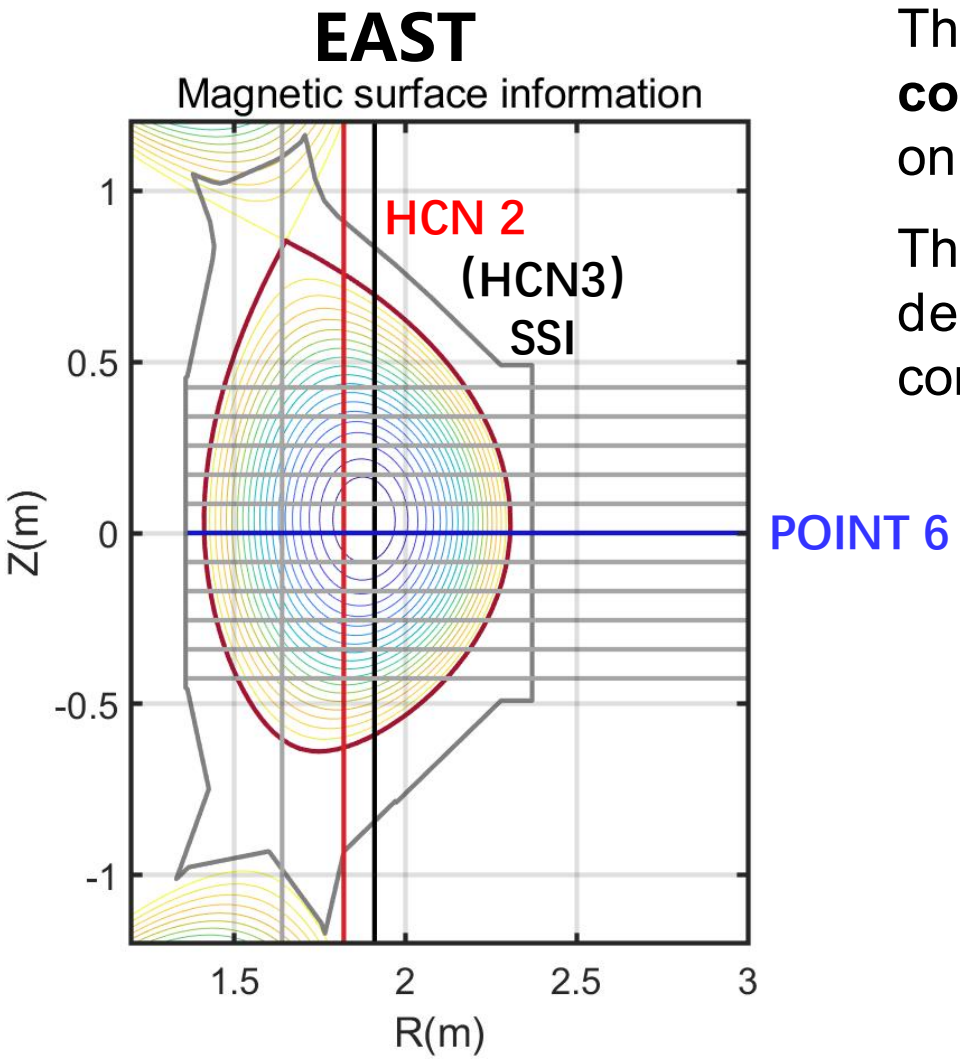
CO_2-pumped HCOOH lasers
(0.694THz)

◆ Solid-source interferometer (SSI)



Solid-state source
(0.65THz)

FIR interferometers on EAST



Information about interferometers on EAST

The study of particle confinement and transport in the **plasma core region** is critical in recent physics experimental research on EAST.

The three interferometer systems on EAST have probe beams designed to measure electron density through the plasma core region.

- **POINT_N6： horizintal O port (Z=0 m)**
- **HCN_N2: vertical K port (R=1.82 m)**
- **SSI: vertical K port (R=1.91 m)**

Interferometer	Wavelength	Manufacture
HCN	337μm	Vertical, single path; 3 chord
POINT	432μm	Horizontal, double path; 11 chords
SSI	461.5μm	Vertical, single path, 1 chord

motivation

- The **spatial resolution** of the single-channel and multi-channel interferometer system is limited by the current optical system arrangement.

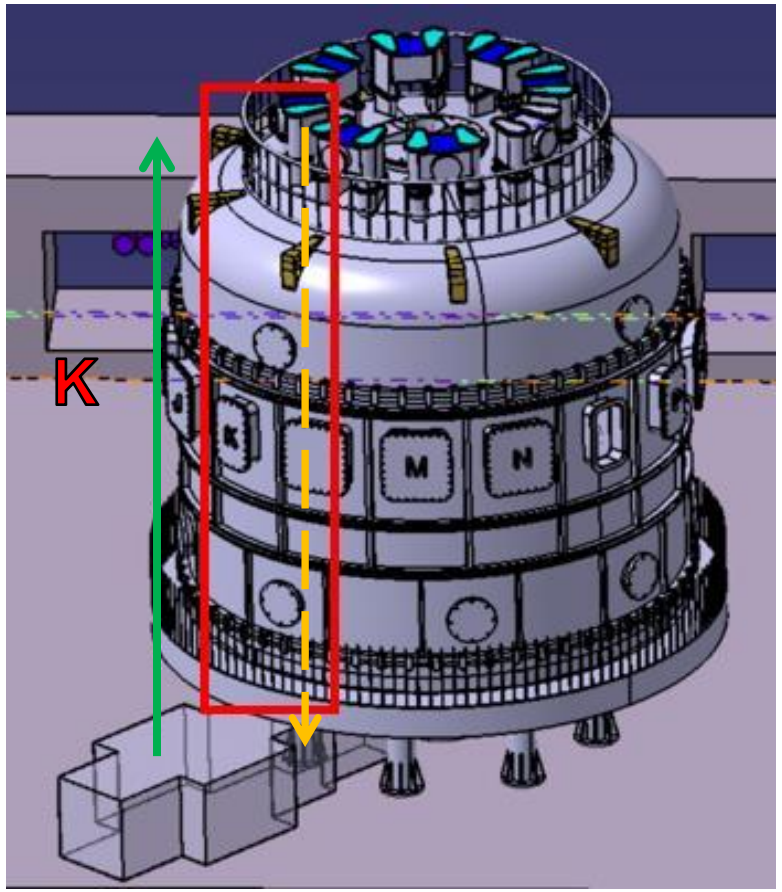
- The **core region plasma** is the key to the particle confinement and transport on EAST. Motivated by improving the spatial resolution and providing technological means for the study of non-global physical phenomena induced by MHD instabilities effects, a higher spatial resolution measurement is needed.

- A **line array detection scheme** is proposed for spatial resolution upgrade on the core region of plasma.

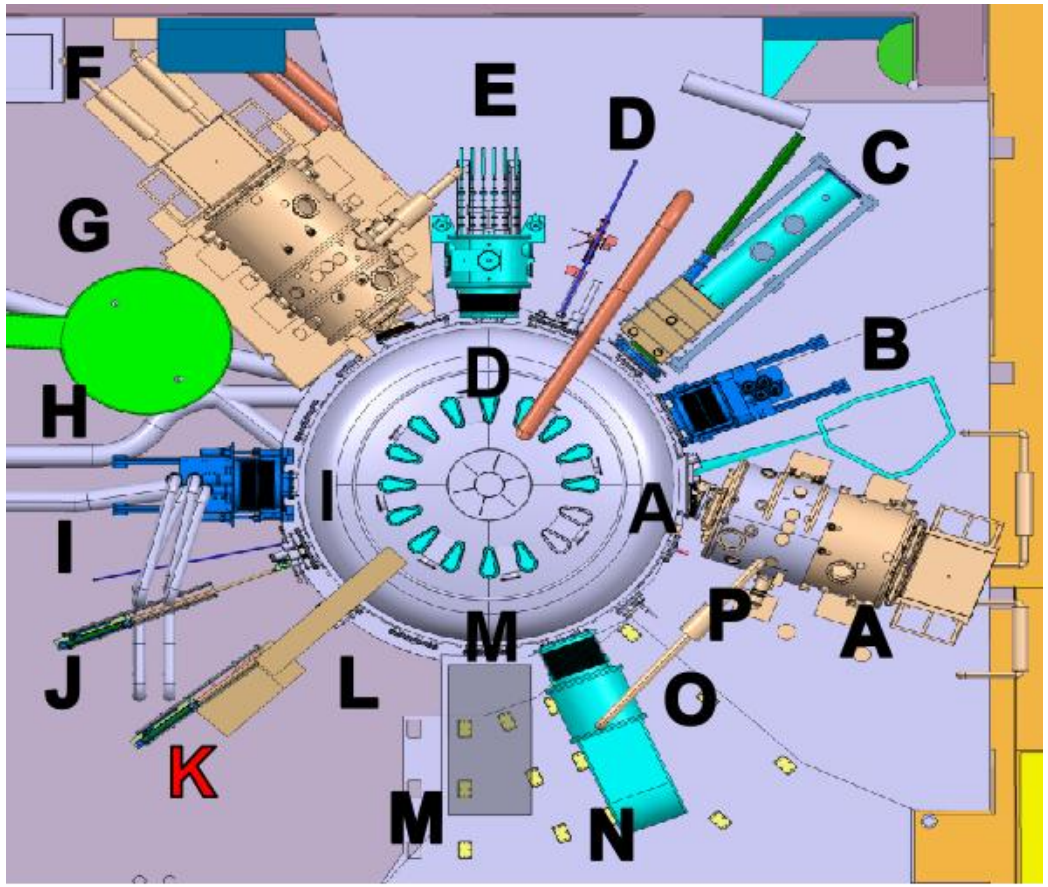
2. SSI system on EAST and Line array detection scheme

The layout of the SSI system on EAST

- a vertical single-channel 0.65 THz solid-source interferometer (SSI) system, installed at the K port of the EAST device.

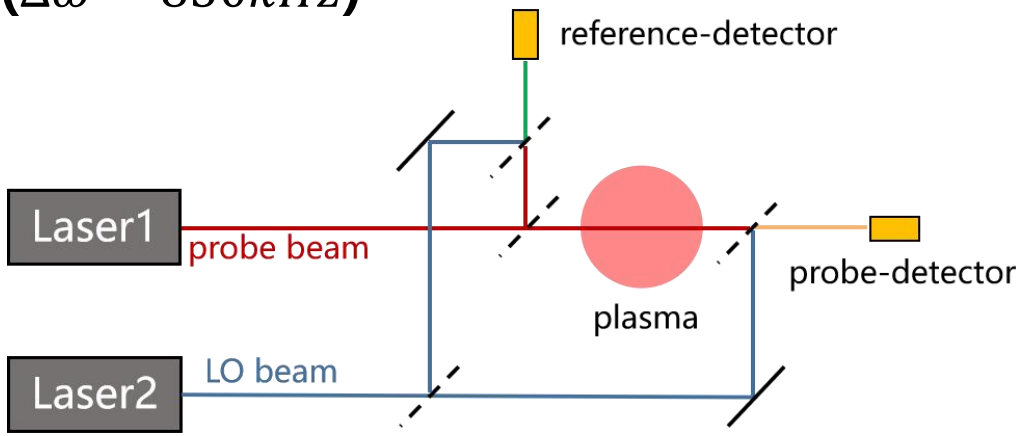


radiation-shielded laser room



0.65THz SSI system

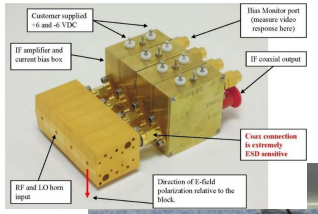
◆ Mach-Zehnder interferometer ($\Delta\omega = 850kHz$)



probe beam $(\omega + \Delta\omega)$ | LO beam (ω)

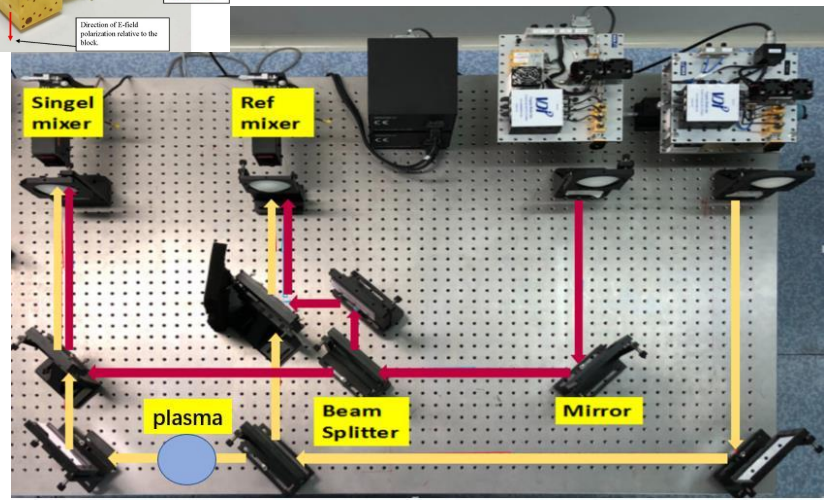
$$I_r = A_0 \cos\Delta\omega t \quad \otimes \quad I_d = B_0 \cos(\Delta\omega t + \varphi)$$

$$\varphi = \frac{\pi}{\lambda n_c}\int n_e dl \quad \Rightarrow \quad \int n_e dl = \frac{\varphi \lambda n_c}{\pi}$$



Schottky barrier diode mixer

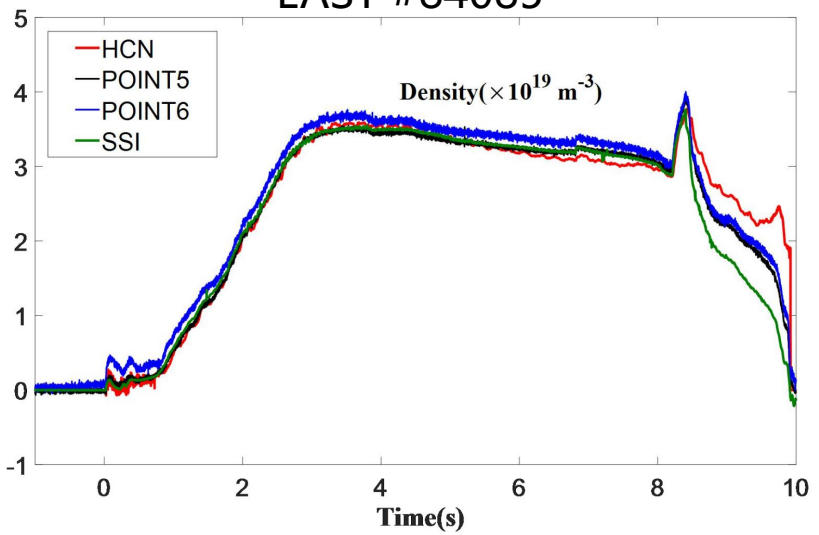
- responsivity of 750V/W



VDI solid-state source

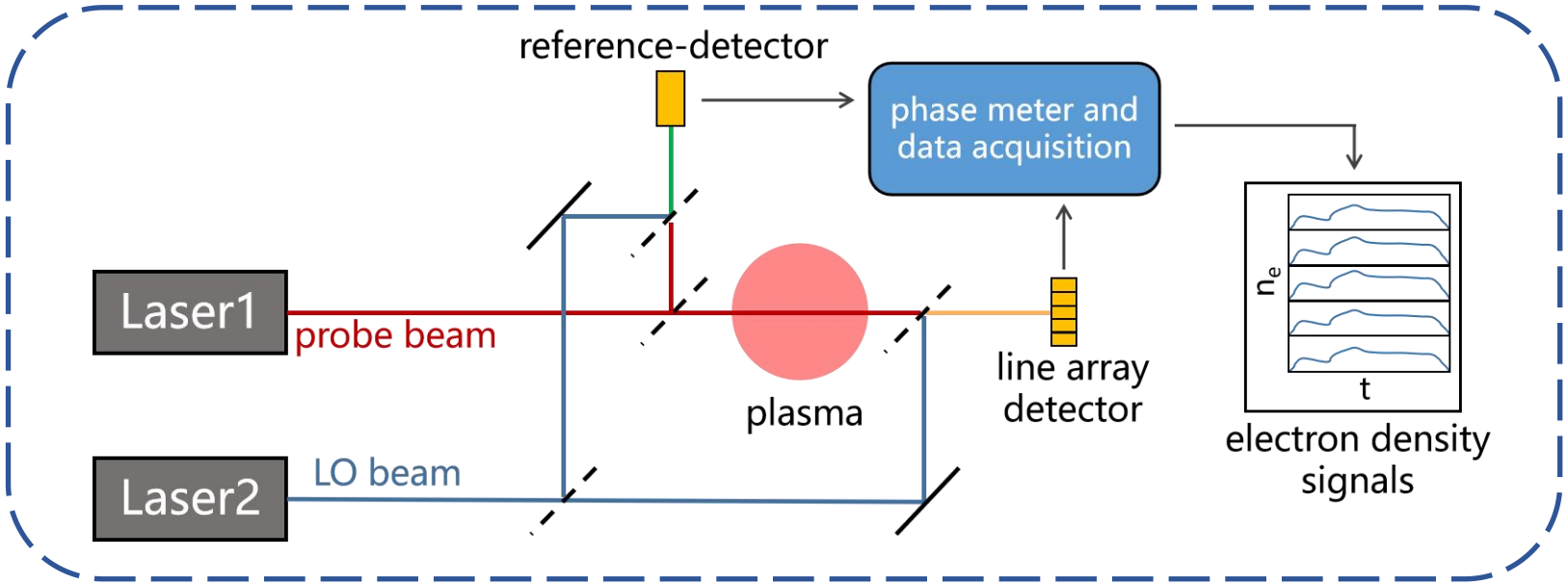
- output power 2.5mW
- frequency range 640-660GHz

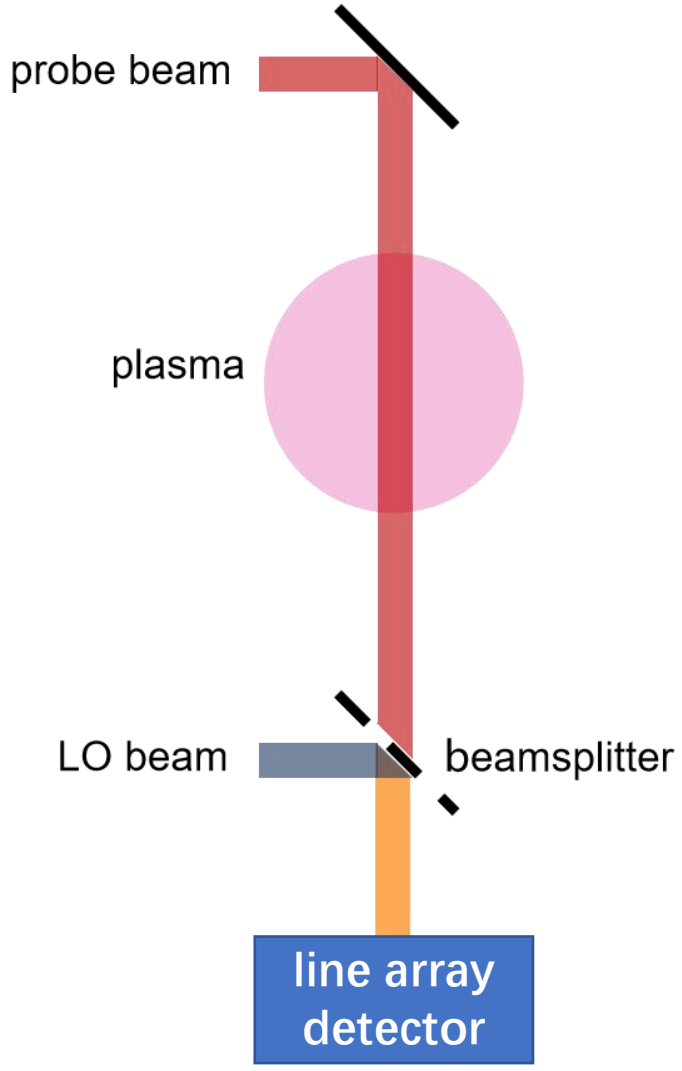
EAST #84085

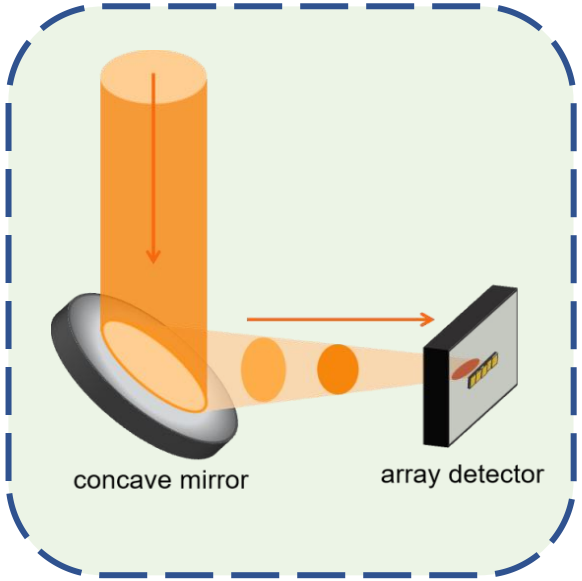


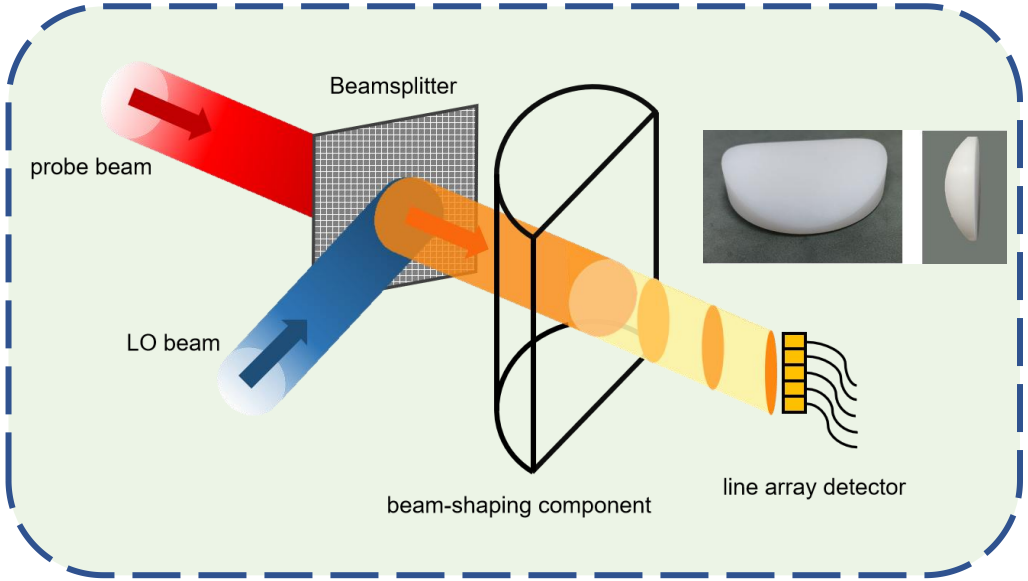
◆ **real-time electron density measurement and feedback control**

The conceptual design of the line array detection scheme



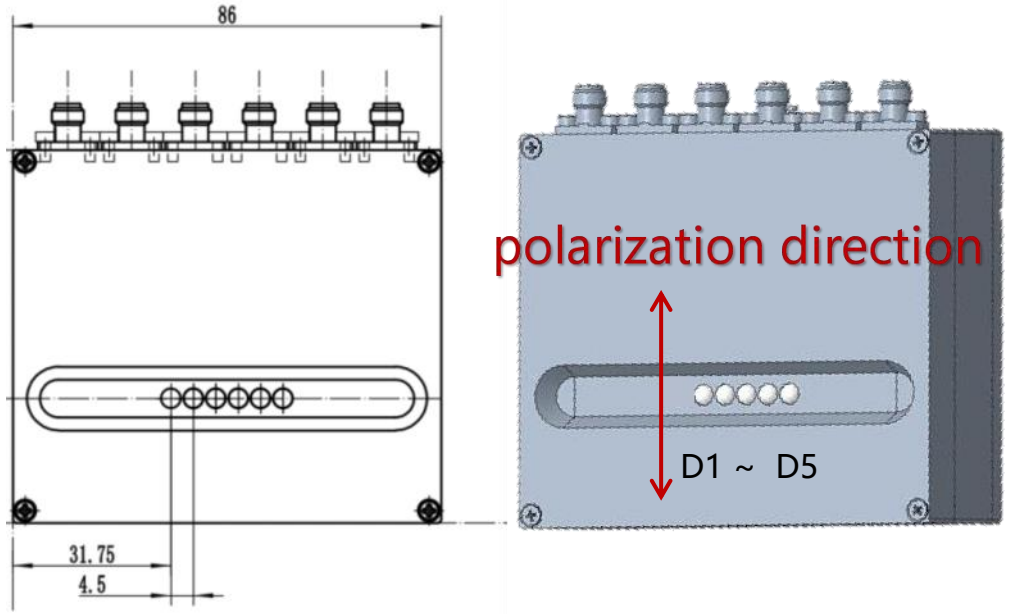


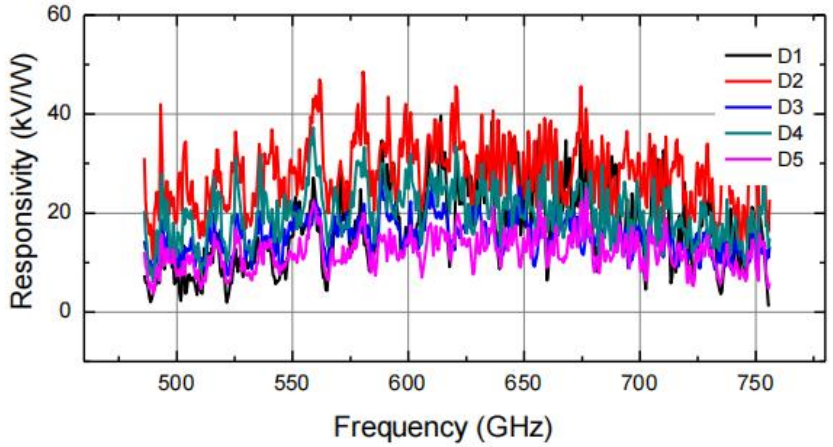


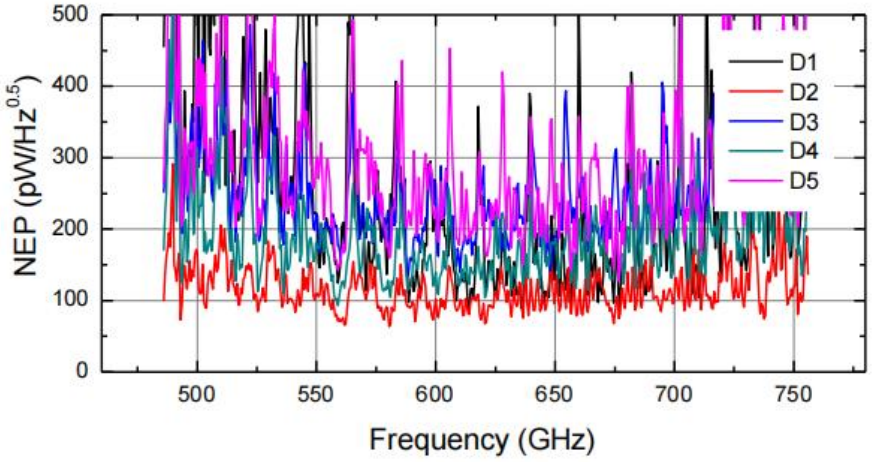


HEMT line array detector

- The IF signals are detected by an AlGaN/GaN line array high electron mobility transistors (HEMT) detector



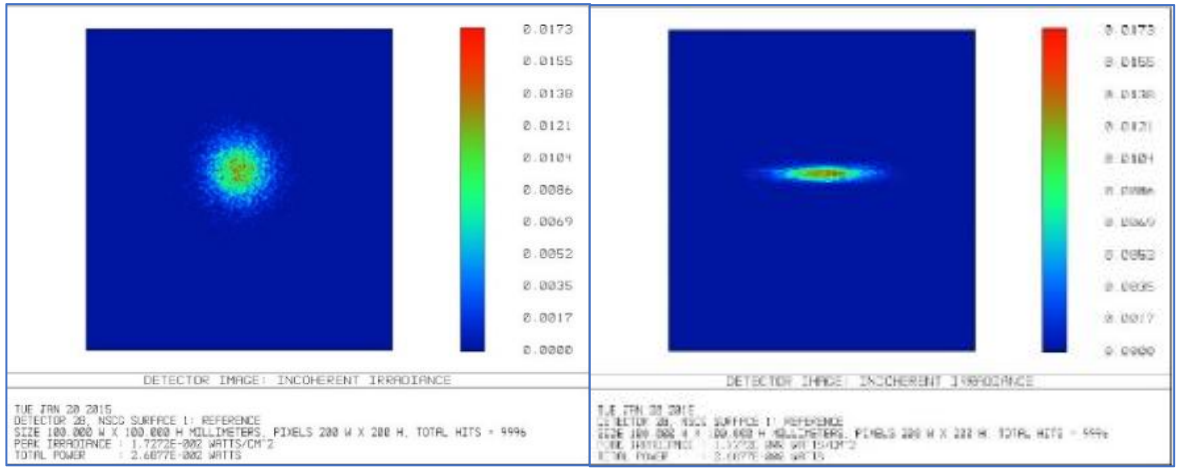




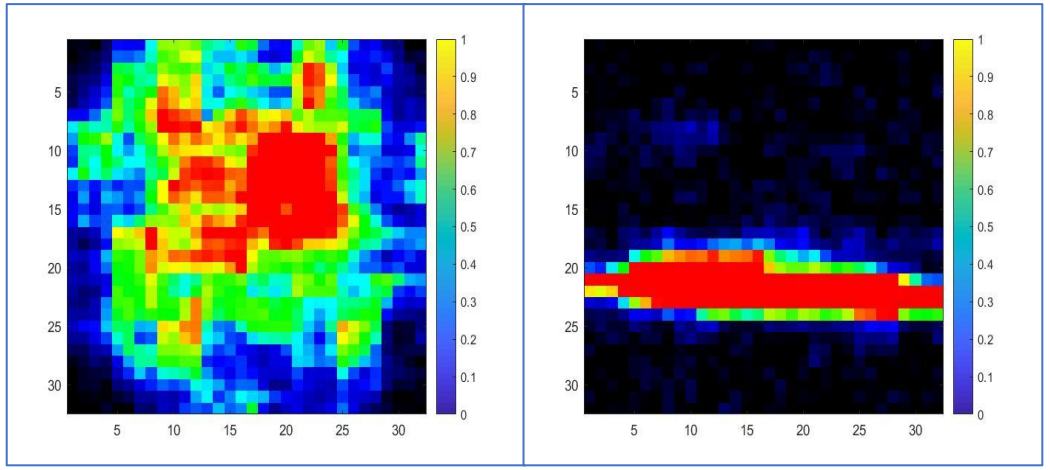
- high responsivity of array element, average is 40kV/W
- 4mm diameter silicon lens on a row with 0.5mm spacing
- powered by a ±6.5V/0.5A linear DC voltage regulator

beam-shaping compenent

- ZEMAX optical simulation results



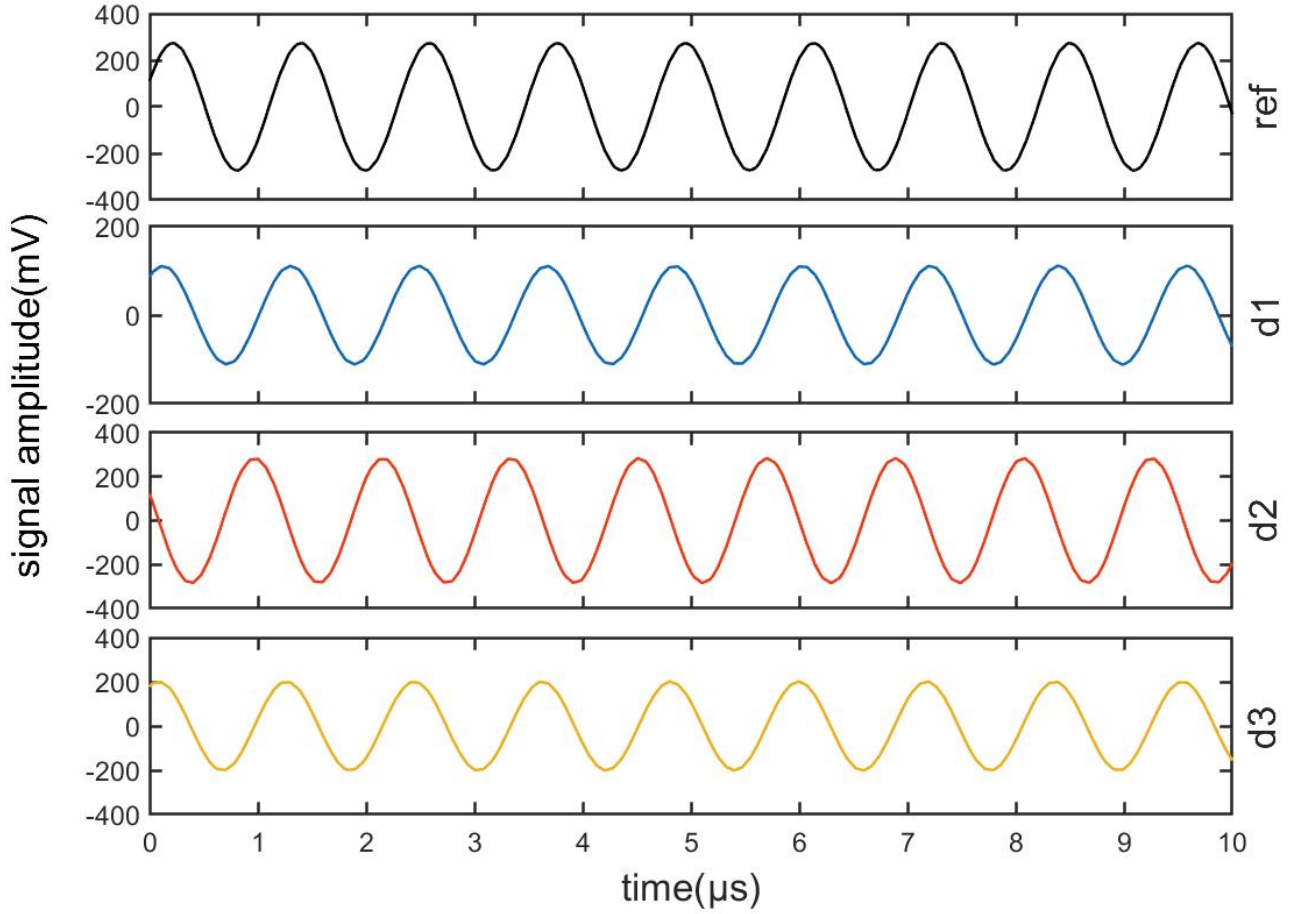
- bench test results



- the laser beam through the cylindrical lens is compressed into a stripe within 4 mm
- bench test results are consistent with simulation results
- good performance of the lens

3. Experiment results and discussion

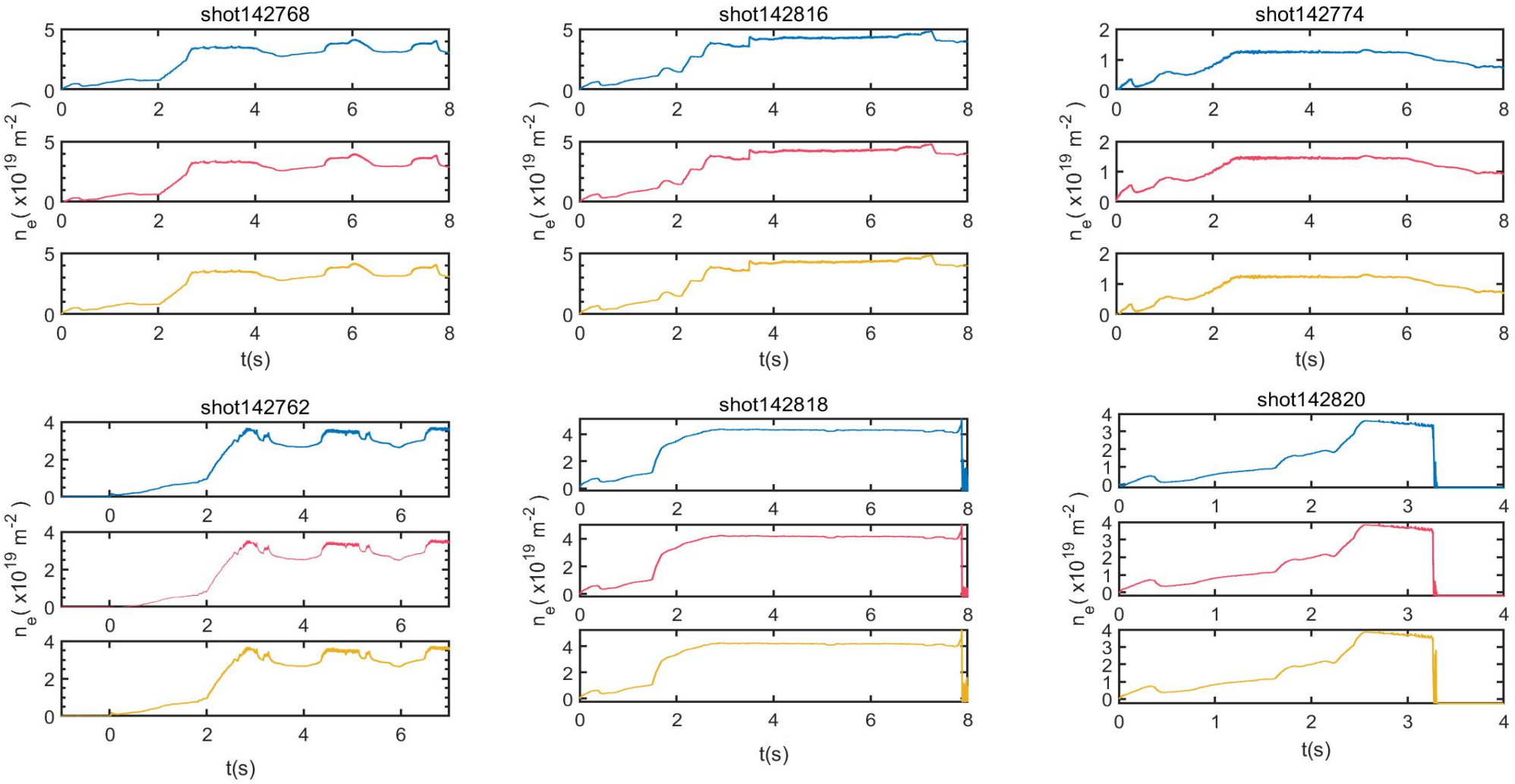
Intermediate Frequency (IF) signals



- key evaluation parameter for an interferometer system
- IF signals detected by the reference-detector and line array detector without plasma discharge

- The results indicate a good response to 850 kHz signals from both the ref-detector and line array detector.
- Differences in the amplitude levels of d1, d2, d3, consistent with the expected result.

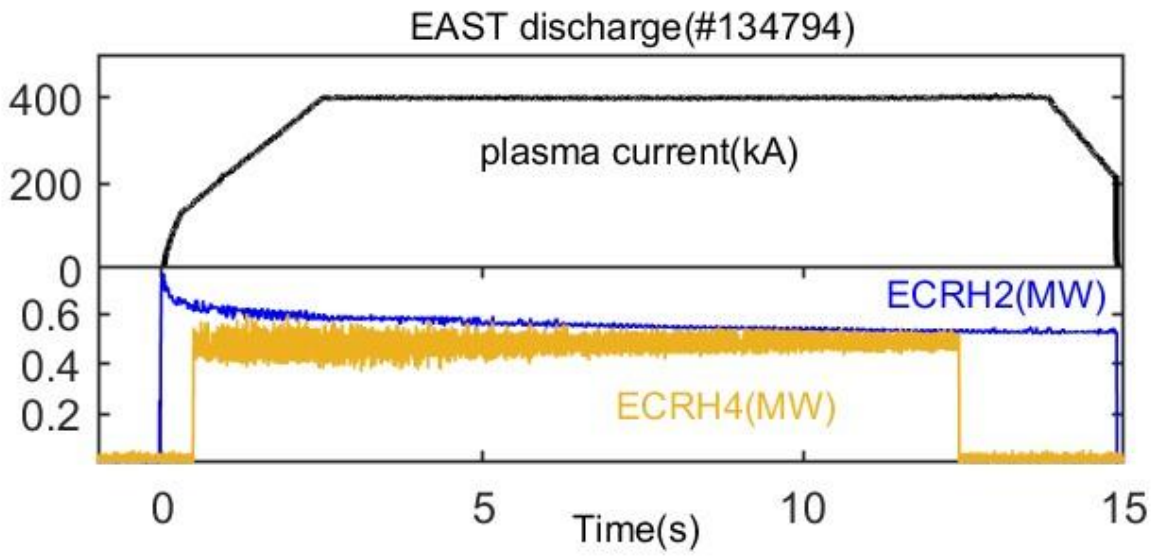
off-line calcution results of electron density

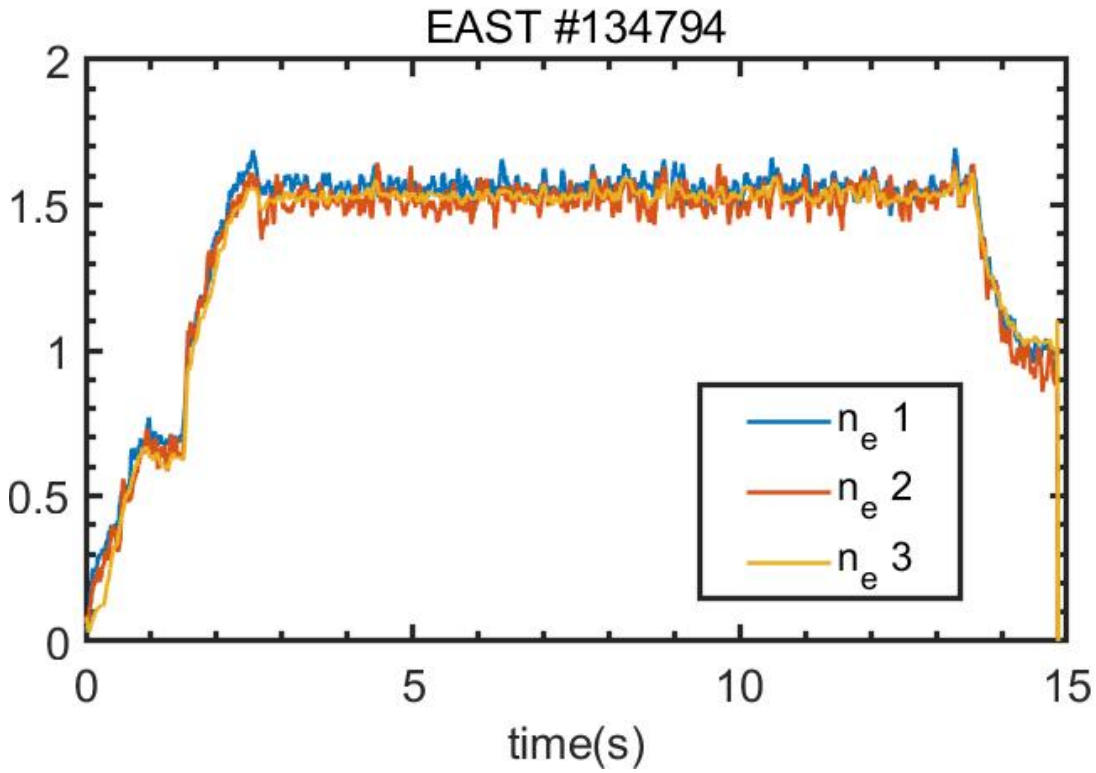


- The three channels density signals can be obtained by off-line phase comparison calculations.

Density measurement by the line array detection

Ip=400kA, n_e= 1.5 × $10^{19}m^{-3}$

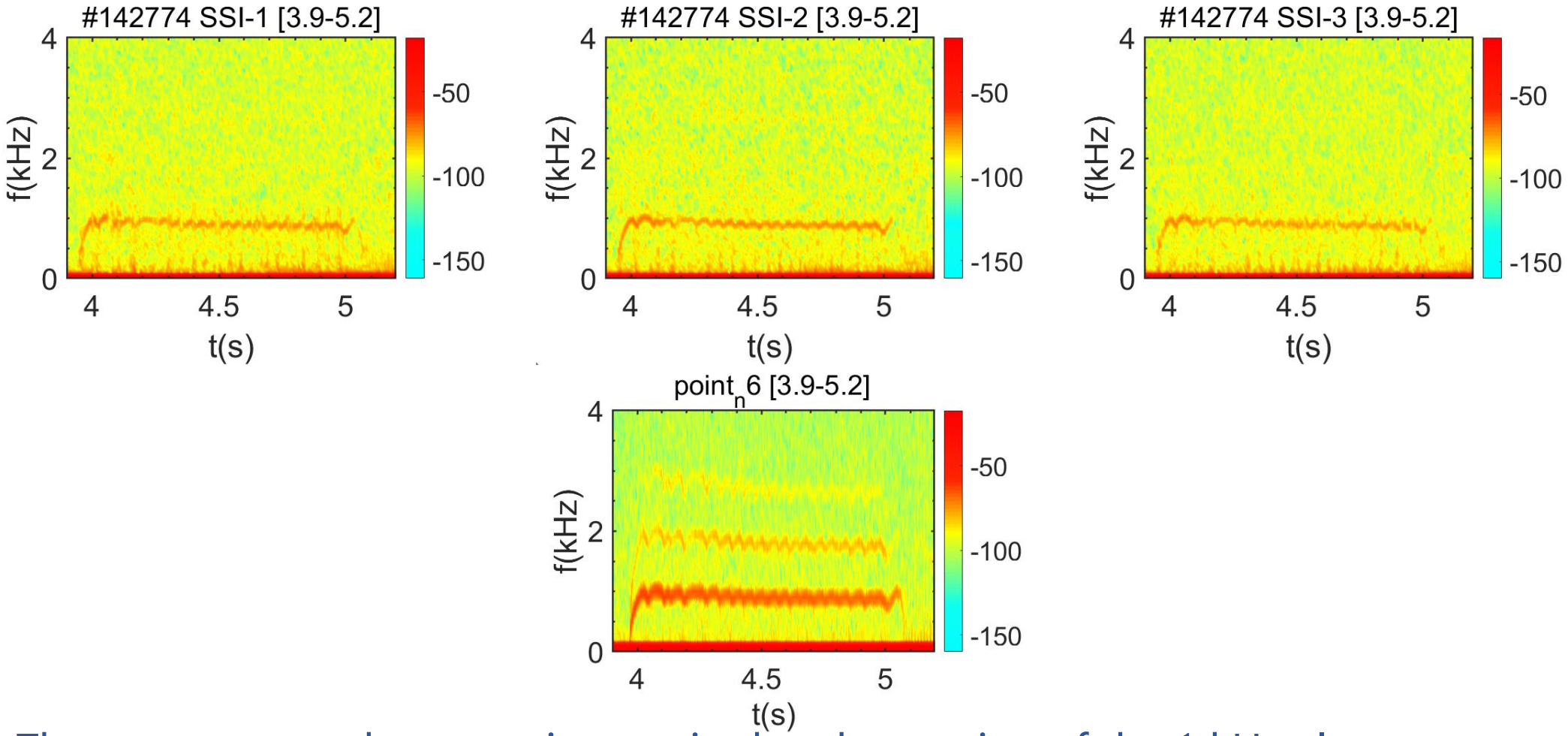




- With the successful application of the phase meter and data acquisition module, real-time array electron density measurements can be implemented during plasma discharge.

Density perturbation phenomenon

EAST #142774 Spectra of SSI and POINT line-integrated electron density signals

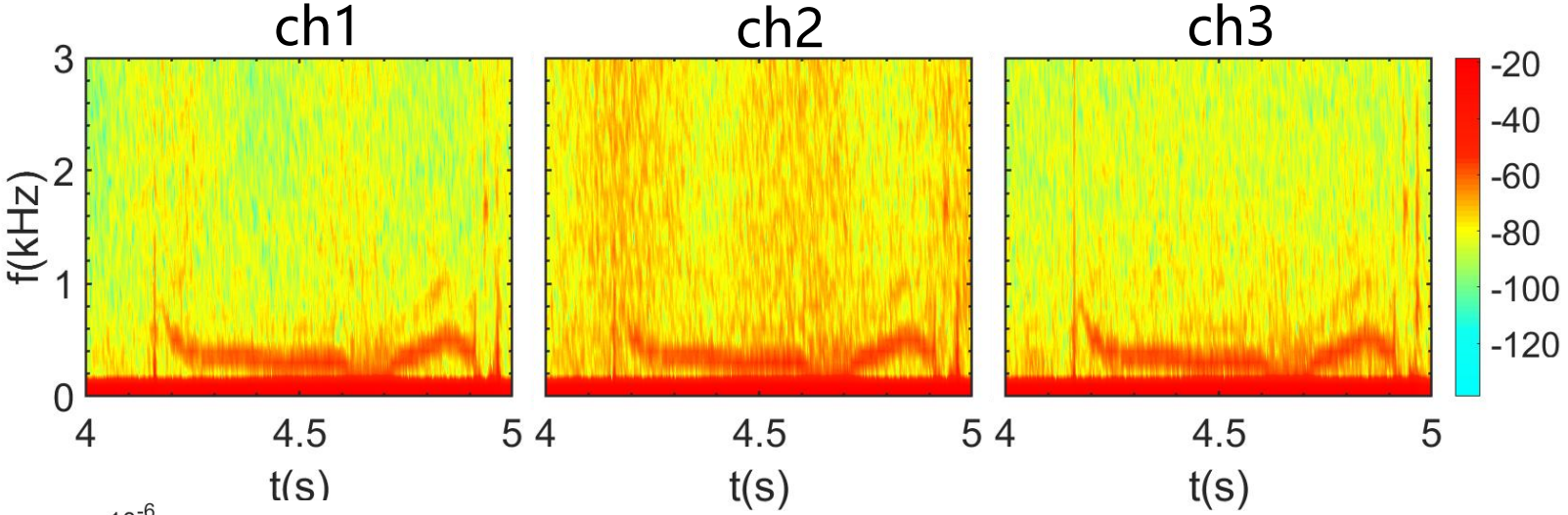


- The two systems show consistency in the observation of the 1 kHz electron perturbation signal

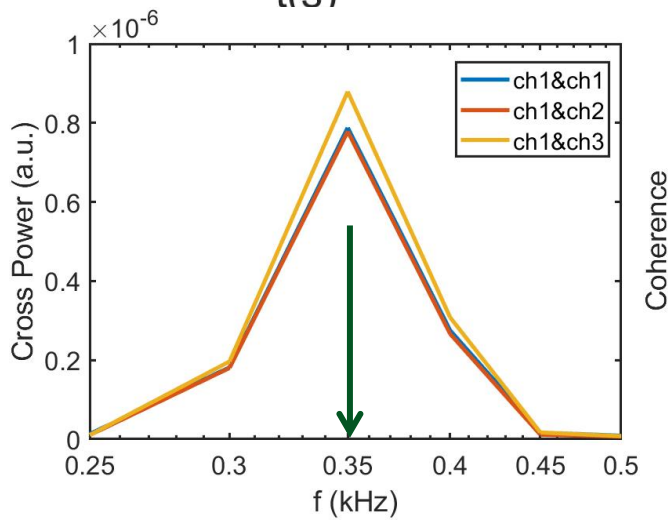
Density perturbation phenomenon

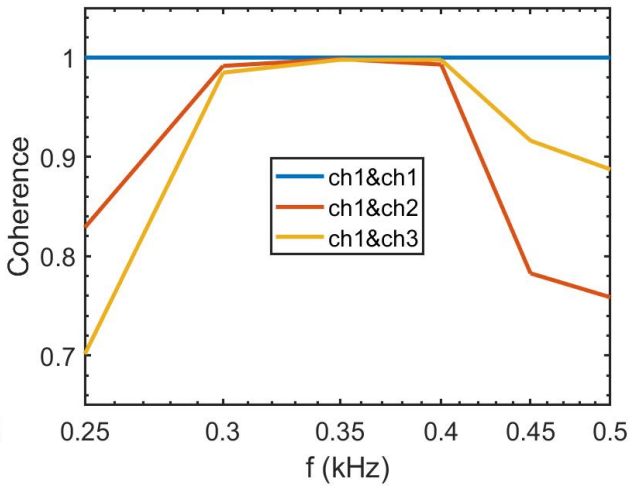
EAST #134788

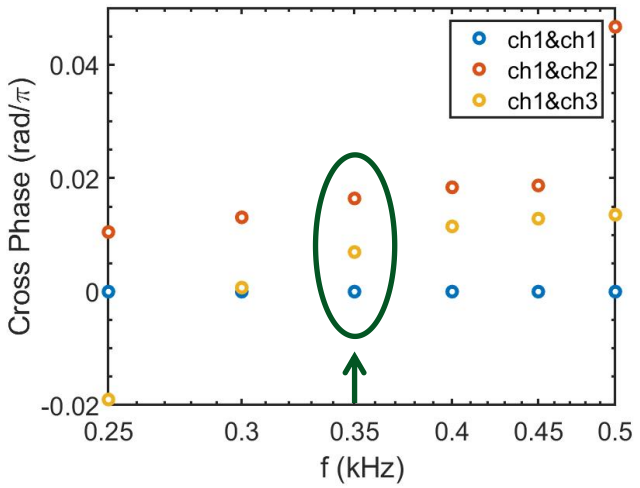
Spectra of SSI three channel line-integrated electron density signals



- 4-5s，0.3 kHz electron perturbation signal
- a fundamental capability to observe density fluctuation phenomenon.







(4.3-4.4s)

Summary

- Line array detection scheme is proposed to improve the spatial resolution of the SSI system, and it has been successfully applied for the first time on EAST.
- Three channels line-integrated electron density signals are detected during plasma discharge by line array detection SSI system.
- The electron density perturbation phenomena are also observed in the spectra of three channels electron density signals, which shows a good capability of the line array detection system to study small-scale spatial MHD phenomena.

Future work

- By optimizing the optical system and improving the channel of the line array detector, the precise measurement of a large coverage area in plasma core region will be realized.

THANK YOU FOR YOUR ATTENTION