

# Progress of the Thomson Scattering Experiment on HSX

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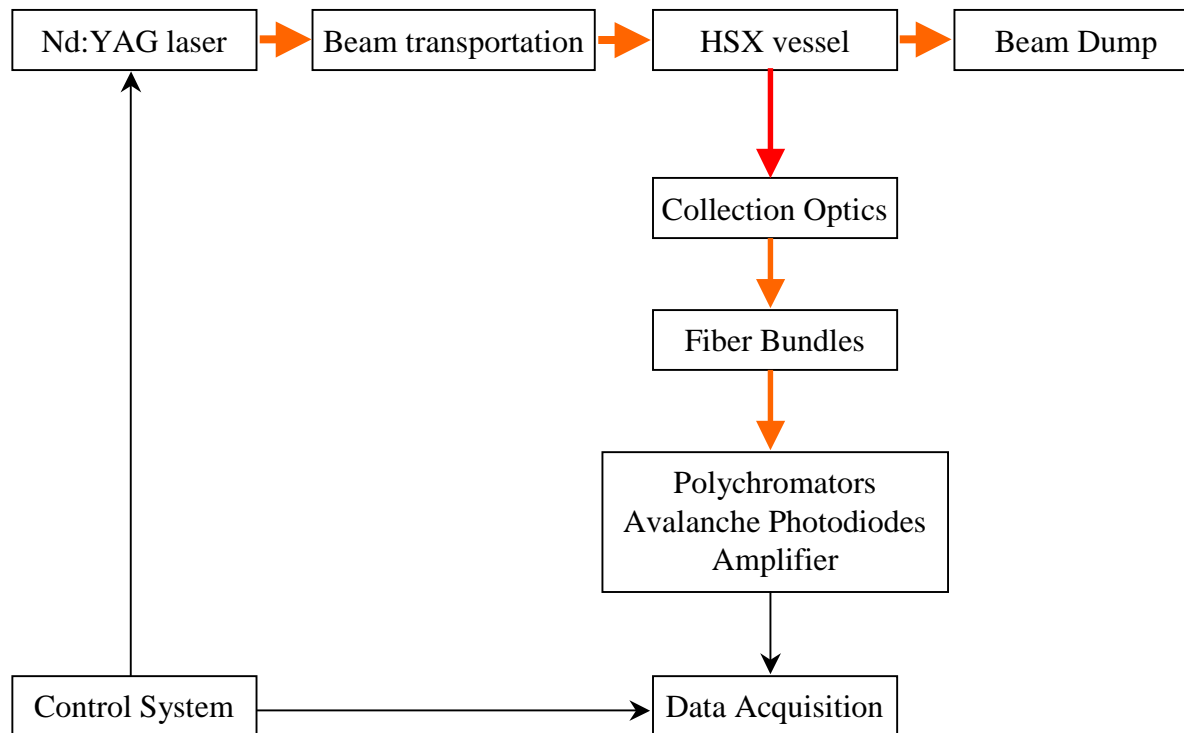
The Thomson scattering system being constructed on Helically Symmetric eXperiment (HSX) in collaboration with GA and UW-MST group will produce accurate single-shot measurement of 10 radial locations for plasma of 10eV—2keV at electron density greater than  $10^{12}\text{cm}^{-3}$ . Double pulse operation will provide measurement of rapid change of plasma parameters. A commercial Nd:YAG laser has already been purchased and tested. Ten filter polychromators designed and manufactured by GA are being checked and calibrated. Design and fabrication of collection lens have been finished. Design of fiber bundles have been finished and are now under fabrication. Mechanic components are now under design and fabrication. A CAMAC electronics system for data acquisition has now been tested. We present the results of component performance measurement and the description of potential system performance. First operation of the system is expected early next year.

\*Work supported by US DoE under grant DE-FG02-93ER54222

# Thomson Scattering System

- Optimized for electron temperature range from 10eV to 2keV
- Ten points profile measurement during one shot
- Double pulse operation for rapid change profile measurement.

# Schematic Diagram of the HSX Thomson Scattering System



# Interdependent Subsystems

- Laser system
- Beaming transportation and stray light control
- Collection optics of the scattered light
- Spectrum dispersion and detection system
- Signal handling and data acquisition
- Control system

# Laser System

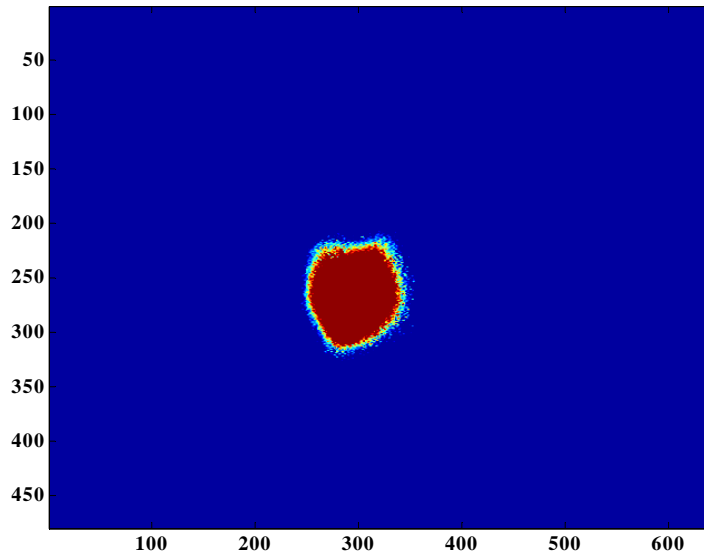
A commercial YAG laser is used as the scattering source.

- 10ns and 1J output pulse at the fundamental wavelength of  $1.06\mu\text{m}$
- Located on optical table in clean room
- Double pulse operation

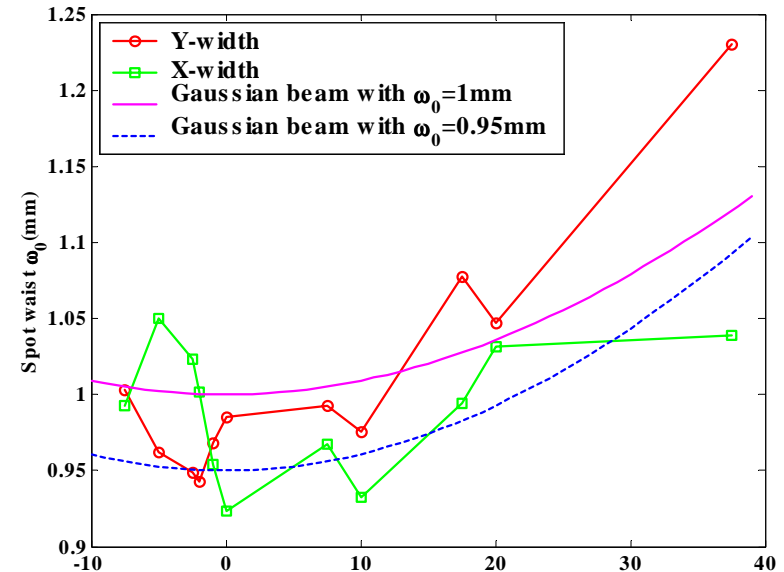
Present status:

- The laser has been checked for the required operation and is ready for experiment.
- The laser will be upgraded to work at 50 Hz in the end of this year.

# Laser Focus Spot Using a 3m Focus Lens



Laser focus spot viewed on a ceramic disc with a CCD camera and video capture card.



Laser spot size relative to the distance with the focus (cm)

# Beaming Transportation and Stray Light Control

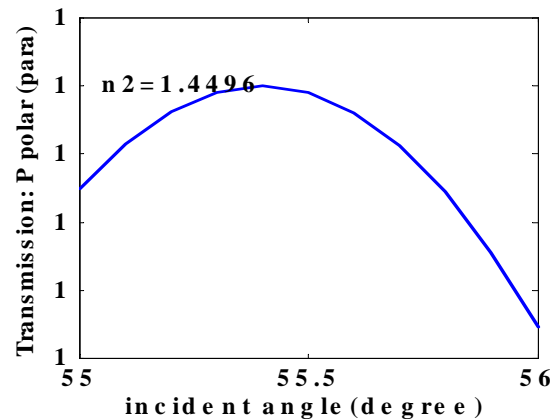
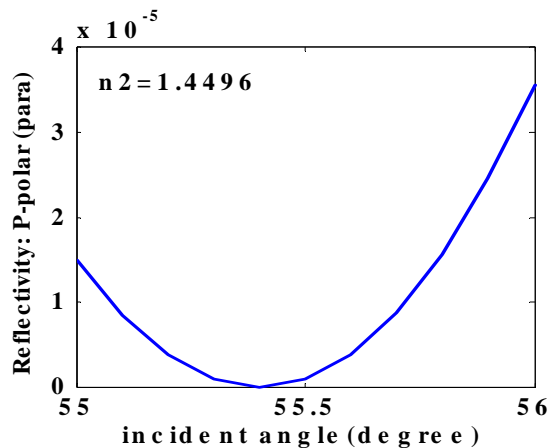
- Beam is guided by three laser mirrors and is focused to the HSX vessel with an  $f=3\text{m}$  focus lens.
- A  $1/2$  waveplate is used to adjust the beam polarization.
- Entrance and exit tubes are specially designed with baffles to control the stray light.
- Entrance and exit windows are Brewster angle orientated fused silica windows.

Present status:

- Tubes and window adapters have been fabricated and now are under vacuum leak check.

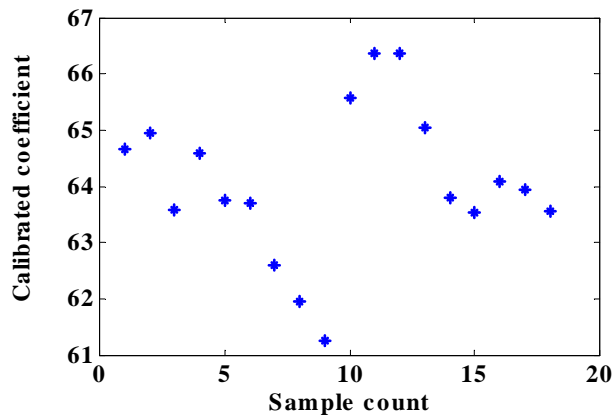
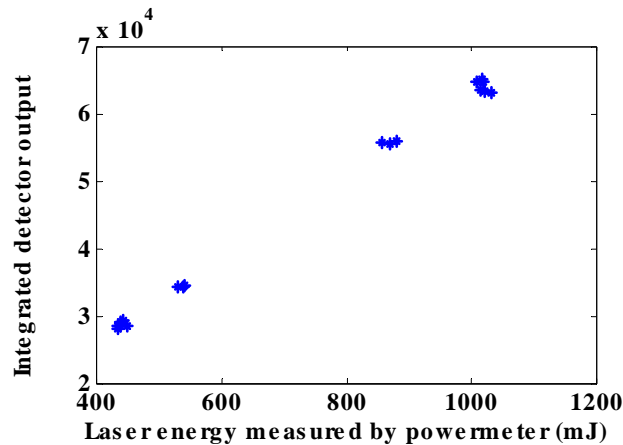
# Entrance Tube and Exit Tube

- Specially designed baffles prevent the stray light reflected from the entrance tube wall from passing into the vessel directly.
- The critical aperture will guide the stray light originating from the entrance window getting into the exit tube.
- Fused silica windows are oriented at Brewster angle to the incident laser.

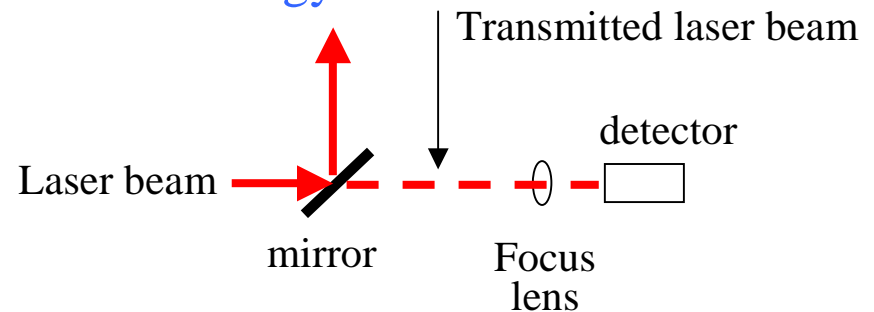


Brewster angled window's reflectivity and transmittance

# Beam Energy Monitor



A PIN detector incorporated with a focus lens is used to **monitor the real time laser energy**.



$$E = (1/C) * D$$

E: Laser Energy

C: Calibrated coefficient

D: Integrated detector output

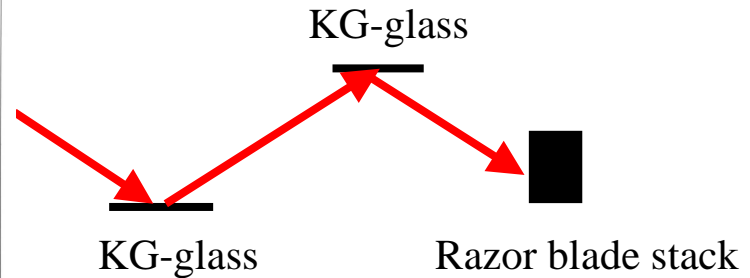
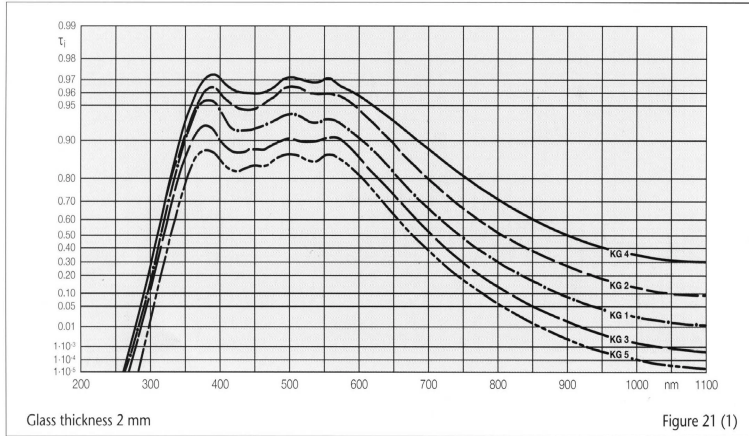
Mean (C) = 64.07, **Standard error = 1.35**

# Beam Dump

A group of KG glass from SCHOTT will be used as beam dump.

Short pass filters

Application as heat protection/cold light filters  
KG 1, KG 2, KG 3, KG 4, KG 5



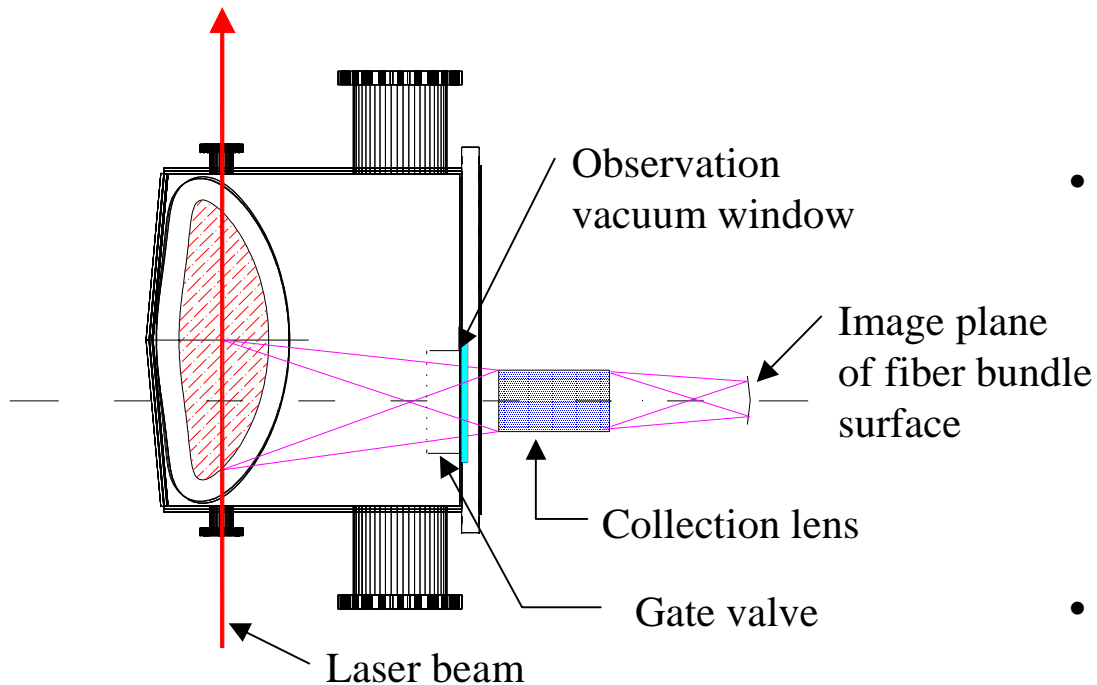
Test laser with a incident angle of 56.5 degree and the incident energy of 1J.

Transmitted energy (mJ)

KG-4-2mm	121	122	124	121	125	123
KG-4-1mm+Kg-2-2mm	24.2	24	23.8	24.4	25	24.4
KG-5-2mm	No response of power meter					

- KG glass works well with laser energy of 1J.

# Collection Optics



Layout of the collection optics with respect to plasma region

- Collection solid angle:  
 $(2.9-3.1) \times 10^{-2}$

attered photons:

$$N_s = \frac{E_0}{hf} \left( \frac{d\sigma}{d\Omega} \right) n_e L \Delta\Omega$$

$$n_e = 1 \times 10^{12} / \text{cm}^3, L = 2 \text{ cm}$$

$$N_s = (2.4-2.6) \times 10^4$$

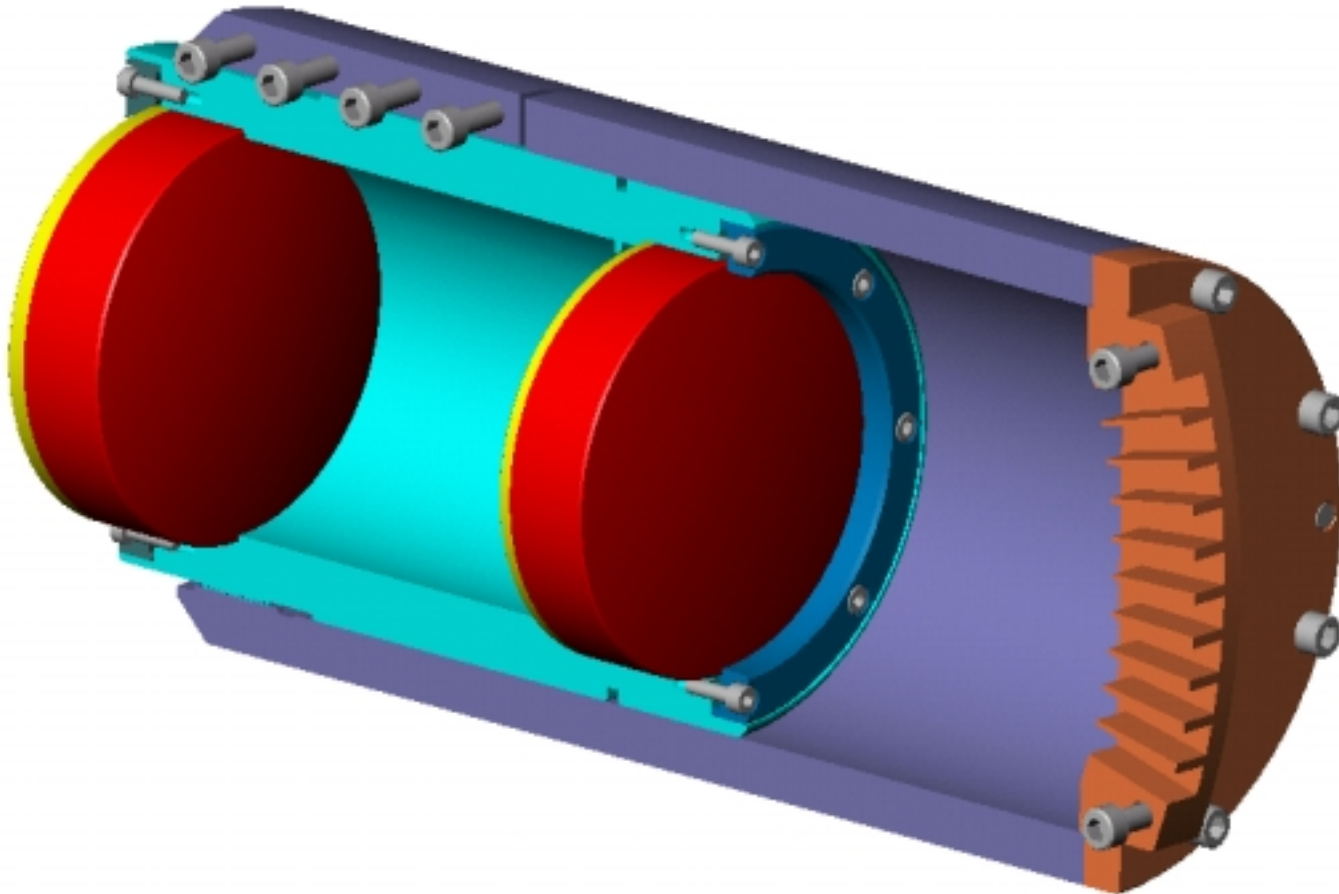
- Spectrum width:

$$\Delta\lambda = 4\lambda_0 \sin \frac{\theta}{2} \sqrt{\frac{2kT_e}{m_e c^2} \ln 2}$$

$$T_e = 10 \text{ eV} - 2 \text{ keV}, \theta = 76^\circ - 104^\circ$$

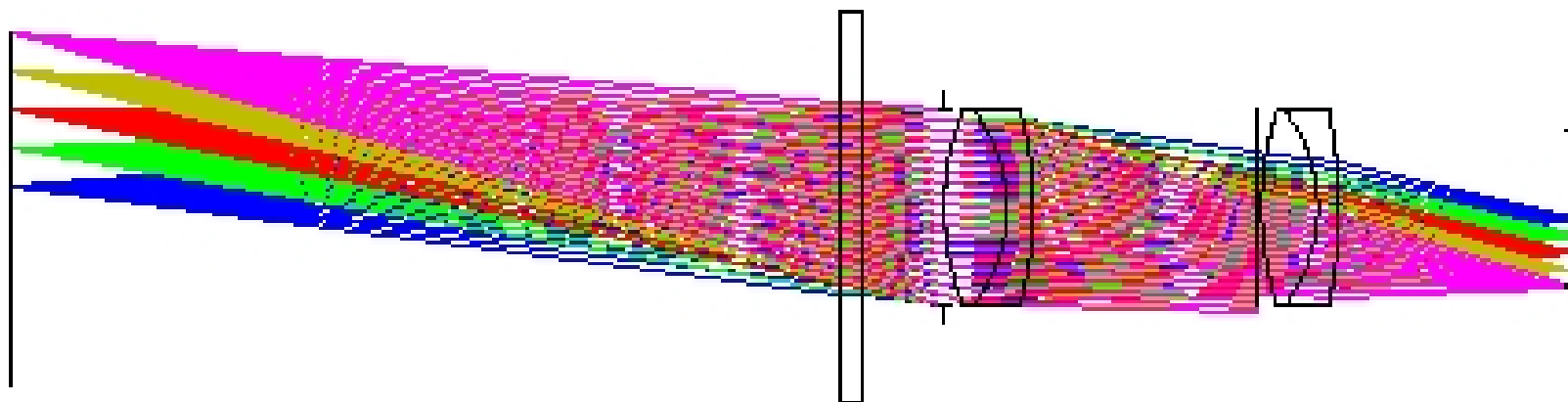
$$\Delta\lambda = 17-246 \text{ nm}$$

# Layout of the Collection Lens and its Coupling to Fiber Bundles



# Optical Properties of the Collection Lens

•System Aperture:	Entrance Pupil Diameter
•Effective Focal Length: (in image space)	16.70 cm
•Back Focal Length:	4.11 cm
•Working F/#:	2.05
•Image Space NA:	0.237
•Object Space NA:	0.11
•Paraxial Magnification:	-0.459
•Entrance Pupil Diameter:	10 cm
•Entrance Pupil Position:	4.66 cm
•Exit Pupil Diameter:	20.11cm
•Exit Pupil Position:	-40.03cm
•Primary Wave:	1064 nm
•Angular Magnification:	0.49

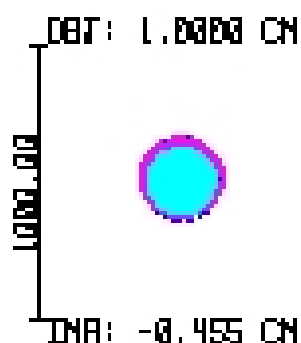


# LAYOUT

HSX THOMSON SCATTERING COLLECTION LENS  
TUE NOV 6 2001  
TOTAL LENGTH: 75.57000 CM

HSX PLASMA LAB

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CONFIGURATION 1 OF 1



OBT: 3.0000 CM



IMA: -1.363 CM

OBT: 5.0000 CM



IMA: -2.261 CM

OBT: 7.0000 CM



IMA: -3.142 CM

OBT: 9.0000 CM



IMA: -4.001 CM

+	1.0600
x	1.0000
-	0.9500
*	0.9000
+	0.8500
■	0.6328

SURFACE: IMA

### SPOT DIAGRAM

HSX THOMSON SCATTERING COLLECTION LENS

TUE NOV 6 2001 UNITS ARE MICRONS.

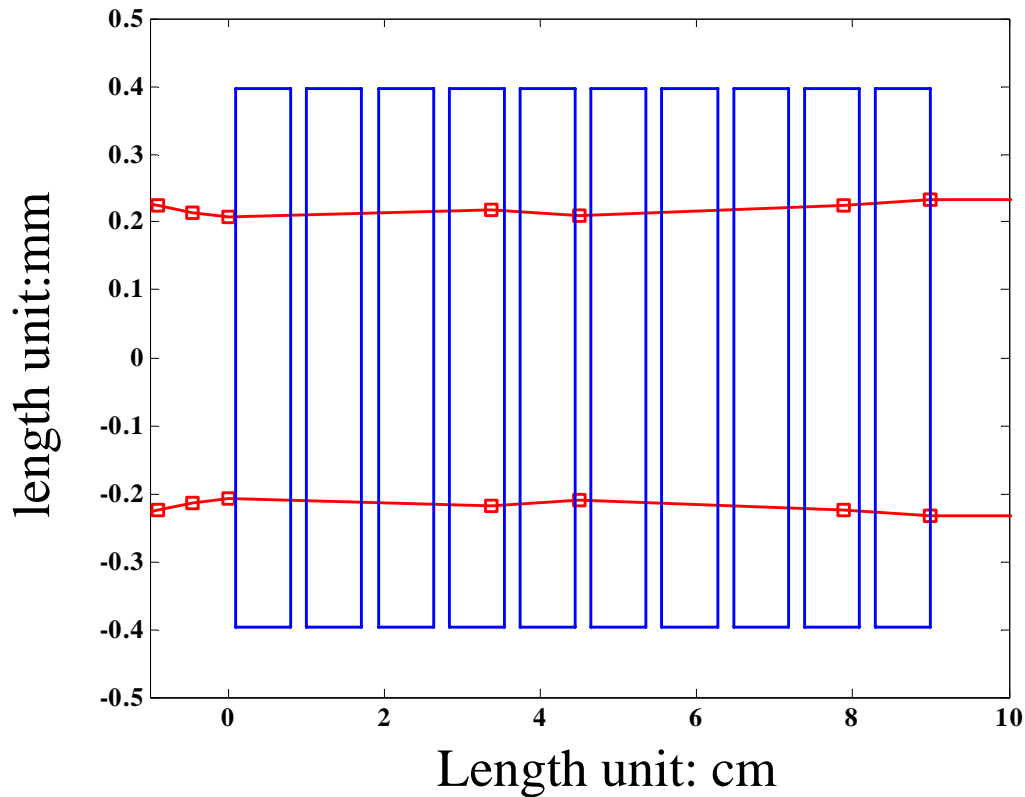
FIELD :	1	2	3	4	5
RMS RADIUS :	72.056	77.788	82.061	81.869	80.713
GEO RADIUS :	147.713	185.553	204.636	203.593	194.943
SCALE BAR :	1000	REFERENCE : CENTROID			

HSX PLASMA LAB

D:\WORK\COLLECTION\_OPTICS\_ZEMAX\COLLECTION.ZMX  
CONFIGURATION 1 OF 1

# Coupling to Fiber Bundles

Laser beam image on the fiber surface



Each square corresponds to an individual fiber bundle's rectangular surface of  $0.8\text{mm} \times 7\text{mm}$

# Spectrum Dispersion and Detection System

- Ten identical polychromators designed and manufactured by GA.
- Four wavelength channels in each polychromator optimized for the measurement of the electron temperature range from 10eV to 2keV.
- Silicon avalanche photodiode detector ( EG&G C30956E ) and amplifier provided by GA are attached to the polychromators.
- Output from the amplifier range from 0.0 to -1.0 volt.

Present status:

A collaboration with MST group in this university is ongoing for the spectral calibration of these polychromators.

# Signal Handling DATA System and Control system

- A computer controlled CAMAC system dedicated for HSX Thomson scattering experiment.
  - A GPIB crate controller from KINETICS SYSTEM is used to communicate between the CAMAC crate and the computer.
  - The signal is recorded by gating Leroy Model 2250 charge integrating digitizer. These digitizers have a sensitivity of 0.5pC/count, with a range of 512 counts.
- A NI 6602 timing card is used for the timing of the system. The outputs of the 8 counters with an internal clock of 80MHz provide delay and gate signal for the system, synchronized with HSX system.

# Summary

- **Ten-point** Thomson scattering measurement on HSX at the electron density of  $10^{12}/\text{cm}^3$  or higher
- Polychromators optimized for **10eV-2keV** temperature measurement.
- Some parts of the system have been tested, and some parts are under design and fabrication. The system is expected to be operative early next year.

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