Upgrade of the HSX Thomson Scattering System

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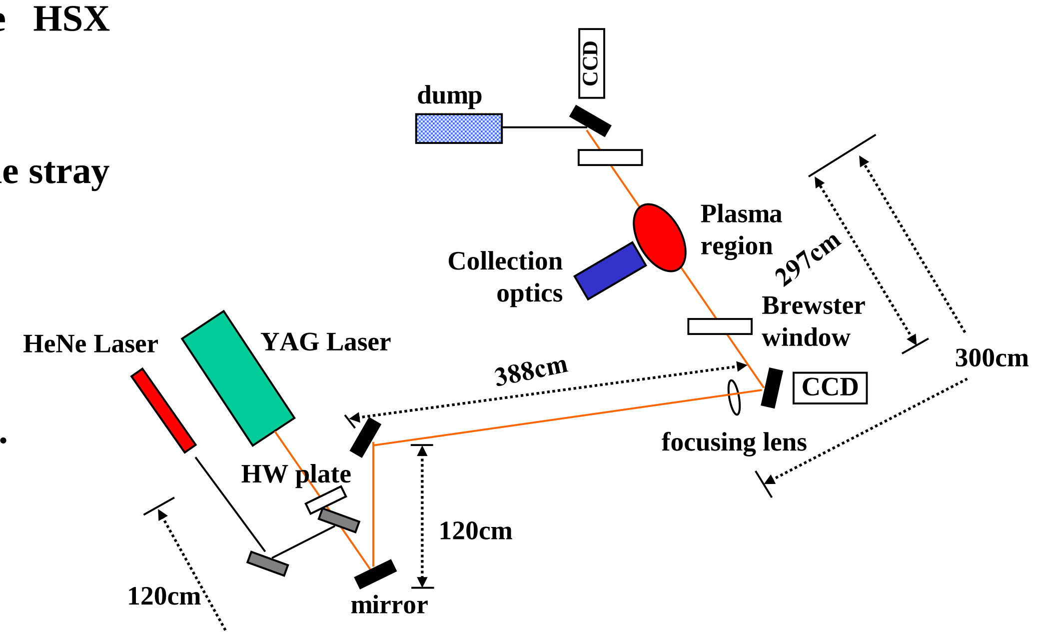
HSX TS upgrade requirement

At the HSX plasma laboratory, the ongoing experiments require a Thomson scattering system to provide time evolution of the electron density and temperature profiles. For example, the second ECH system which permits variation of heating power and location during a plasma discharge to study the internal transport barrier formation and transient thermal conductivity measurements, the laser blow-off experiments to study the impurities transports in the HSX plasma, the biasing electrode experiment to study the radial electric field effects, etc. To facilitate these experiments, efforts to upgrade the current HSX Thomson scattering system to have multi-shot adjustable time resolution have been carried out.

Current system

Beam path

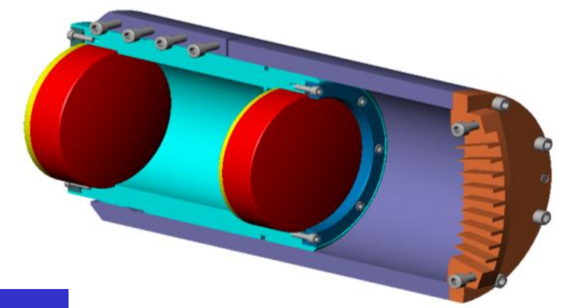
- The laser beam is guided by three laser mirrors and is focused to the HSX vessel with a f=3m focus lens.
- A half waveplate is used to adjust the beam polarization.
- Entrance and exit tubes are specially designed with baffles to control the stray light.
- Entrance and exit windows are Brewster angle orientated fused silica.
- A HeNe alignment laser is used to align the collection optics.
- Two CCD cameras are used to monitor the beam position.
- Two KG-5 glass groups and a razor blade stack are used as beam dump.
- The whole laser path is enclosed inside solid material for safety reason.

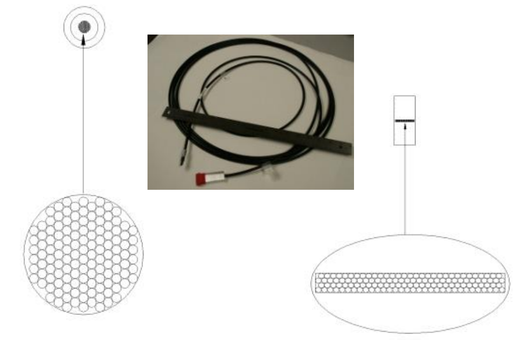


Collection optics

The collection lens collects scattered laser photons and couples to the polychromator through fiber optics.

- The collection lens consists of two doublets made of BK7 and SF1 glass. The image spot is less than 100 microns for all the ten channels.
- There are 126 individual fibers in each bundle, each fiber is selected with a numeral aperture around 0.24-0.25 to match the output collection lens and the input of the polychromator. Total length is 7 meters for each bundle.





Circular end couples to the polychromator.

Rectangular end couples to the collection lens.

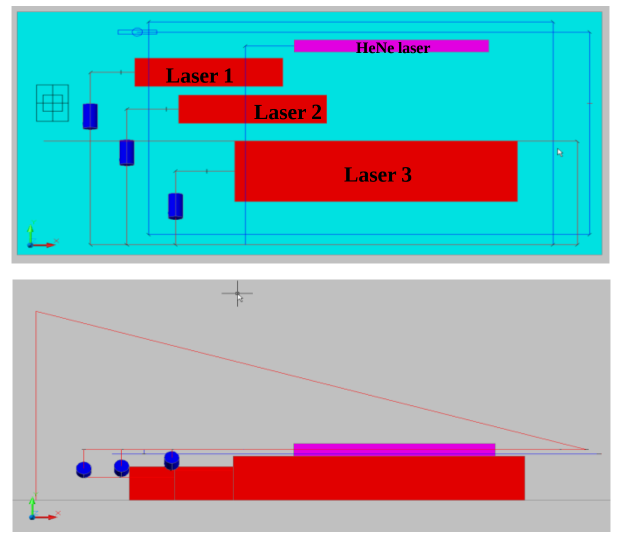
Polychromator and data acquisition

- Ten identical polychromators designed and manufactured by GA are used to disperse the scattered light. Four wavelength channels in each polychromator are optimized for the measurement of the electron temperature range from 10eV to 2keV.
- A LabView program controls the timing and data acquisition of the system.
  - 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.
  - System synchronization of laser pulse and digitizer gate with a DG535 digital pulse generator from Stanford Research Systems.

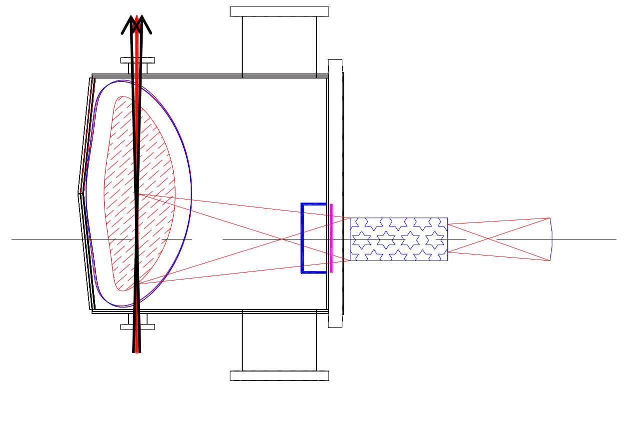
New system

Beam Path

Three Nd:YAG lasers will be used for the upgraded system. Each beam is guided by six mirrors. After each beam passes through its own half wave plate for polarization adjustment and its energy monitor optics, the three beams will be combined together. The distance from the laser to the plasma region is 12m.



Top and side view of lasers arrangement



Three laser beams converge at the plasma region.

The three beams will be combined in the plane of poloidal cut of plasma crosssection. Thus the beams are not shifted from side to side with respect to the collection optics; instead the beams are shifted backward or forward with respect to the collection optics. Since the beams are separated by 2cm at the distance of 12m, this backward and forward shift is expected to be 0.17mm at most in the scattering region. Zemax® ray tracing shows the beam image holds within 100 microns with this backward and forward of 0.2mm shift.

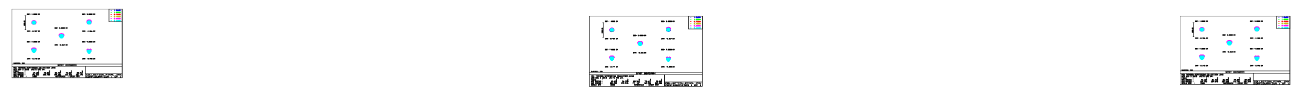
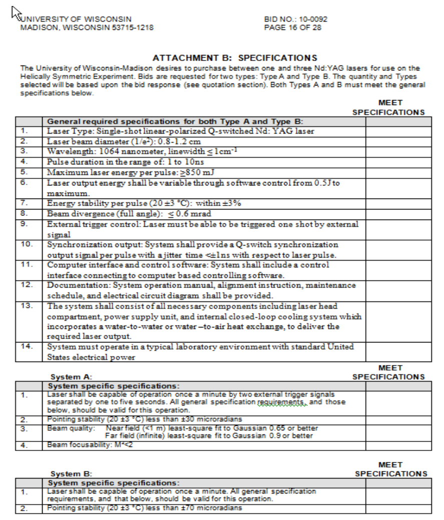
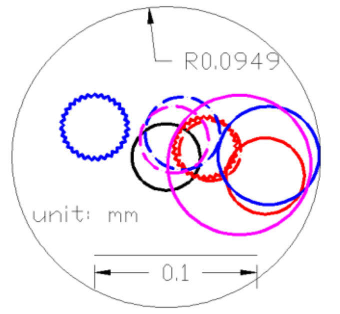


Image quality of object shift -0.2mm (left), 0mm, and +0.2mm (right)

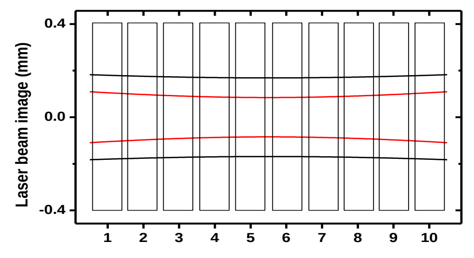
Collection optics and alignment

The upgraded system will use the same collection optics as the current one. For the alignment requirement of the optics, the laser is specified to have pointing stability =30urad and M^2<=2.





We have tested our current laser long term pointing stability. R=0.0949 indicates the 30urad pointing stability. This test lasted for a week period.



Laser beam image on the 10 fiber surfaces: Red-Gaussian beam, Black-M^2=2 beam. Each square corresponds to an individual fiber bundle's rectangular surface of 0.8mm*7mm

- Alignment requirement for the HSX TS optics parameter: focusing lens focal length =300cm, beam diameter = 1cm
  - For a Gaussian beam, the spot diameter at the focus point is 0.4mm. The +-5% diameter change occurs at Z=15.2cm, which means the focused spot size within +-15cm of the focal point along the beam path is within 0.42mm.
  - If M^2 is less than 2, the focused beam size is within 0.84mm in plasma region. The collection optics has an image magnification of 0.46, thus the image size on the fiber is under 0.39mm. The fiber has a width of 0.788mm. This gives a misalignment margin of 0.4mm on fiber surface, which is 0.88mm in plasma region. The distance from the laser to the plasma region is 12m, this requires the laser pointing stability to be 36urad or less.

Polychromator and data acquisition

- Polychromator has been modified, each of the five central spatial channels has five spectral channels. This improves the measurement of the central channels at high electron temperature.
- Modified digitizer 2249A on loan from MST group will accommodate 85 in-memory measurements at intervals down to 65 us. It has a sensitivity of 0.25pC/count, with a range of 1024 counts.

Summary

At the HSX plasma laboratory, a single-shot 10 channel Thomson scattering system has been implemented and is now operational. To expand the TS measurement with time resolution to accommodate the ongoing experiments on HSX, efforts to upgrade the current system to have multi-shot adjustable time resolution are in progress. The new system will utilize three Nd:YAG lasers, and outputs will be combined to share the same beam path. The system will use the current collection optics. Modification of the polychromators and the upgrade of the integrator digitizers (on loan from the Madison Symmetric Torus group) have been finished. We have setup the test procedure of the laser to qualify the laser performance to meet with the required specification. Laser procurement is now in progress.

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