# High-k Scattering and FIReTIP Diagnostic Upgrades for NSTX-U

R. Barchfeld[1], E. Scott[1], C.W. Domier[1], C.M. Muscatello[1], P. Riemenschneider[1], M. Sohrabi[1], N.C. Luhmann, Jr[1], Y. Ren[2], R. Kaita[2]
[1]University of California, Davis, [2]Princeton Plasma Physics Laboratory
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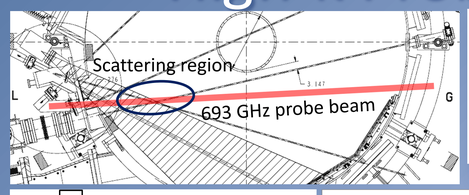
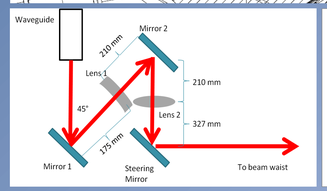
## High-k Scattering System

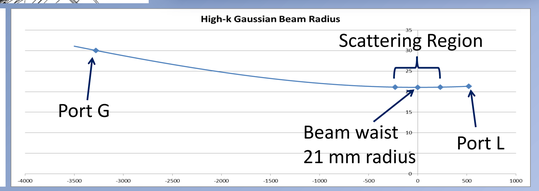
The High-k Scattering system is undergoing significant improvements for installation on NSTX-U in 2016. The system has been reconfigured for $k_\theta$ detection geometry, and the probe frequency has been increased from 280 GHz to 693 GHz. The reduced wavelength in the poloidal system will result in less refraction and, together with the new poloidal scattering scheme, will extend the poloidal wavenumber coverage from the previous 7 $cm^{-1}$ up to 40 $cm^{-1}$. Initial installation will include a 4x1 pixel receiver array; however, it is expandable to an 8x2 array.

## High-k Probe Beam

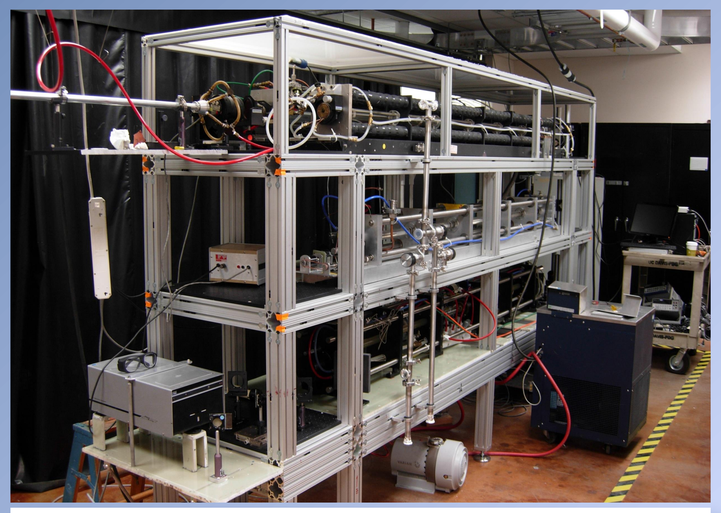



A series of mirrors and HDPE lenses will direct the 693 GHz probe beam from port G to port L.



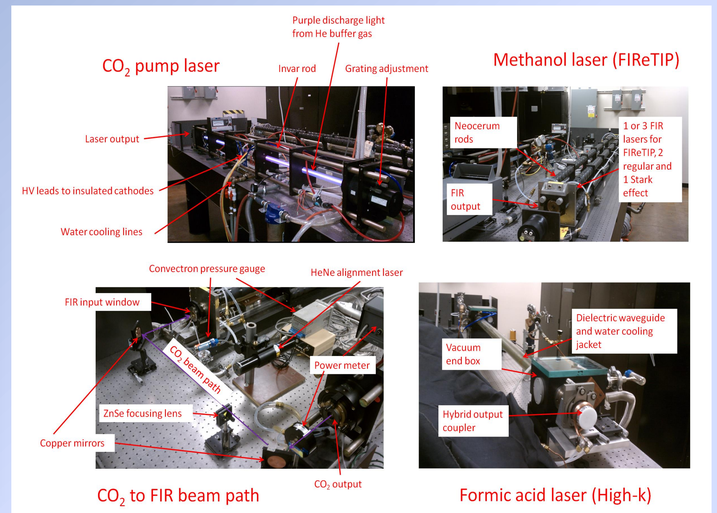




## Laser Table



3 level laser table housing 6 lasers for High-k Scattering (1 $CO_2$ pump, 1 formic acid FIR) and FIRETIP (1 $CO_2$ pump, 2 methanol FIR, 1 Stark effect methanol FIR ).

## Laser Details

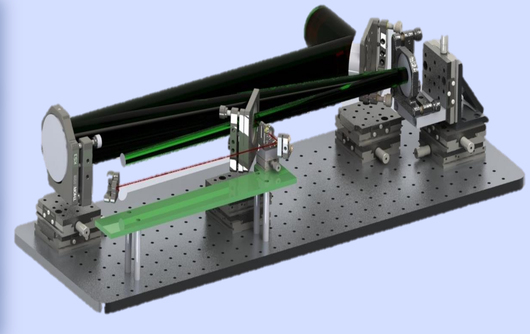



## FIReTIP

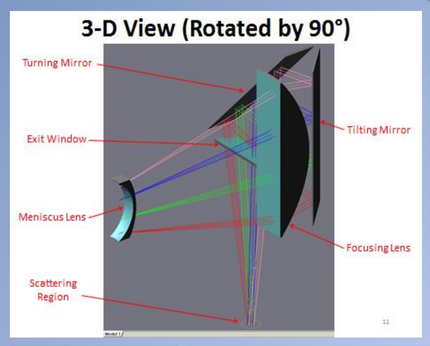
The FIReTIP system has been refurbished and is ready for installation at NSTX-U. The core of the system remains 3 optically-pumped methanol lasers, one of which uses an electric field to induce Stark-broadening. As part of an effort to give NSTX-U real-time density feedback control capability, FIReTIP is being upgraded to provide real-time density information by utilizing a 633 nm heterodyne interferometer and an NI CompactRIO FPGA.

## Front-end Optics

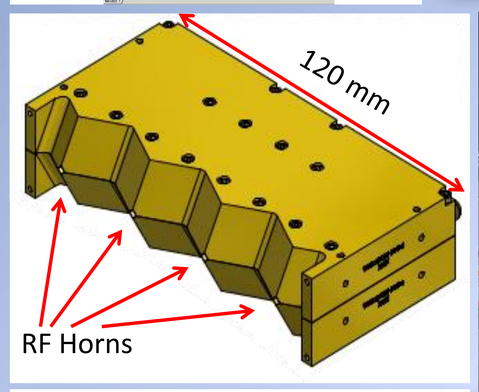
The FIReTIP front-end optics have been designed to provide an FIR beam waist of ~13 mm at the retroreflector as well as a well-collimated HeNe beam with beam radius 10.5 mm.



## Receiving System



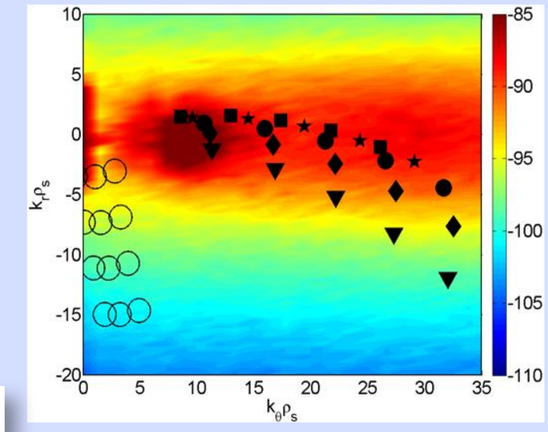

A system of remote control mirrors and HDPE lenses can target various locations in the scattering region. A meniscus lens redirects various scattering angles into parallel rays before being focused into the mixer input horns.




4x1 subharmonic, 693 GHz, mixer array from Virginia Diodes Inc. This modular design allows multiple arrays to be stacked for increased poloidal and radial coverage. Future developments will include an 8x2 array.

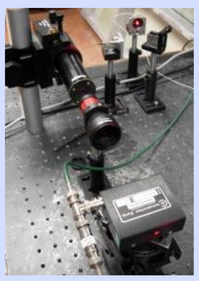
A 33 cm tall window at port L allows for $k_\theta$ up to 40 $cm^{-1}$.

## High-k Scattering Coverage



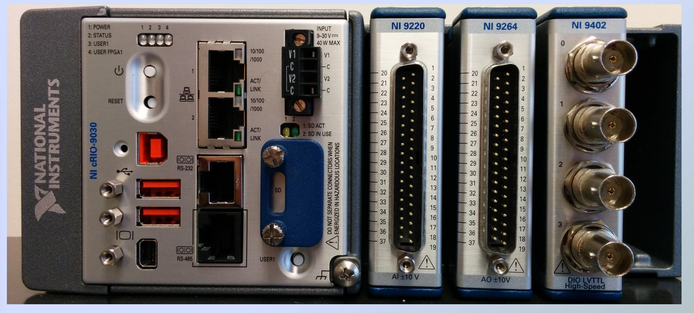

Computer simulation of ETG modes in NSTX-U. Peak modes are expected near $k_\theta$ = 10 $cm^{-1}$ and $k_r$ = 0 $cm^{-1}$. Black symbols show possible coverage from the High-k Scattering System. The open circles show coverage from the previous High-k Scattering system.

## HeNe Interferometer



A 633 nm heterodyne interferometer is being utilized to detect changes in path length of the FIR lasers due to vibrations in the front-end optics and the internally-mounted retroreflector in real-time. The majority of the system consists of fiber optics for low-loss transport of the beam.

## FPGA




An FPGA will analyze and correct the FIReTIP signal for the effects of vibrations using input from the HeNe interferometer in real-time, allowing FIReTIP to be used for density feedback control.