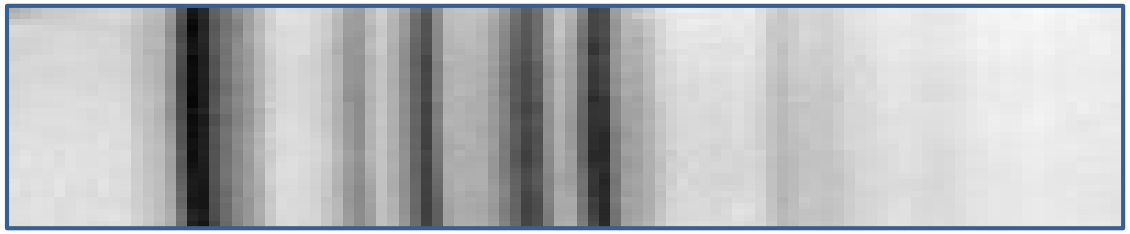

High Resolution Spectra of He-like Fe for ICF

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Yu. Ralchenko[c], M. Karasik[a], V. Serlin[a],
S. Obenschain[a]

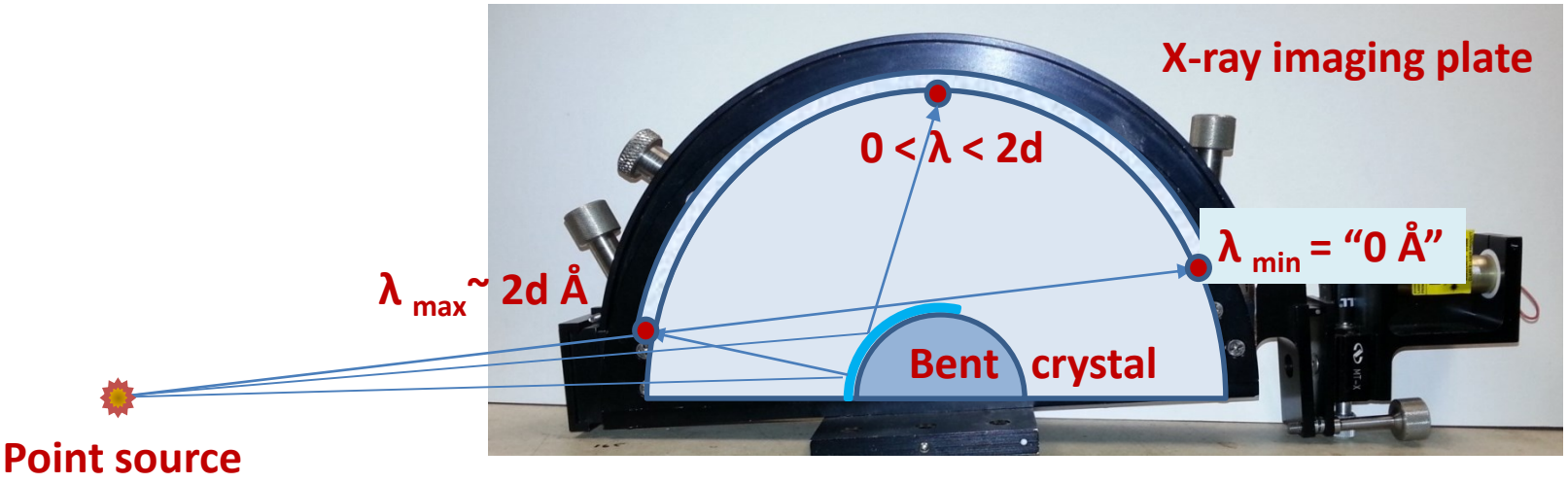
[a]NRL, [b]Leidos, [c]NIST

The NRL Nike laser is capable of delivering on a target kilojoules of ultraviolet light (λ = 248 nm) within several nanoseconds, which is sufficient to produce high-Z ions with multi-keV ionization potentials.

- As such this system is a unique platform to benchmark high-energy-density plasma diagnostics and relevant atomic physics simulations.

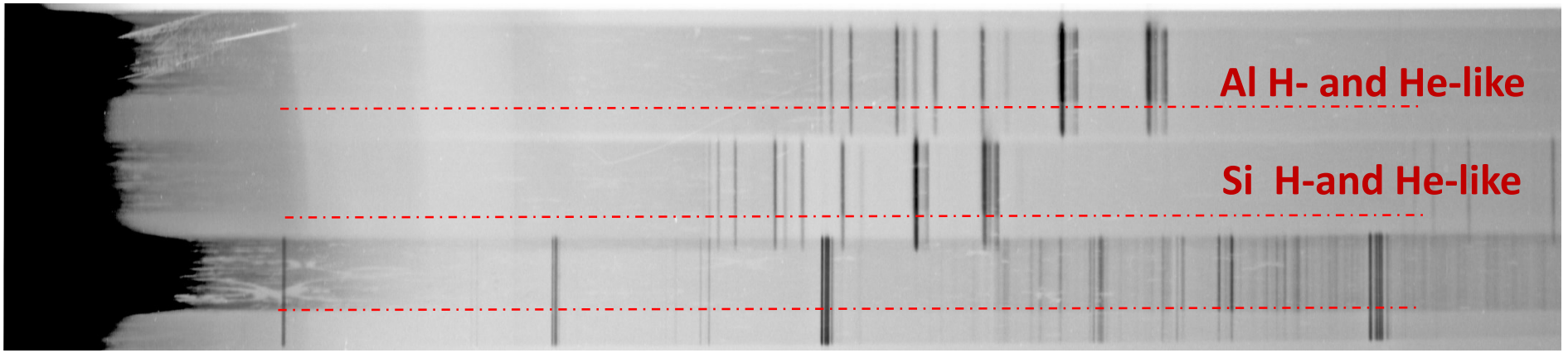
- Collisional-radiative simulations with the NOMAD code were used to model the recorded spectra and to identify spectral lines in the x-ray .

Nike survey “half-moon” convex crystal spectrometer



Crystal : mica, 2d = 20 Å
Working orders of reflection:
n= 1,2,3,5,7…..
λ/Δλ > 1000

Highly ionized iron from survey spectrometer



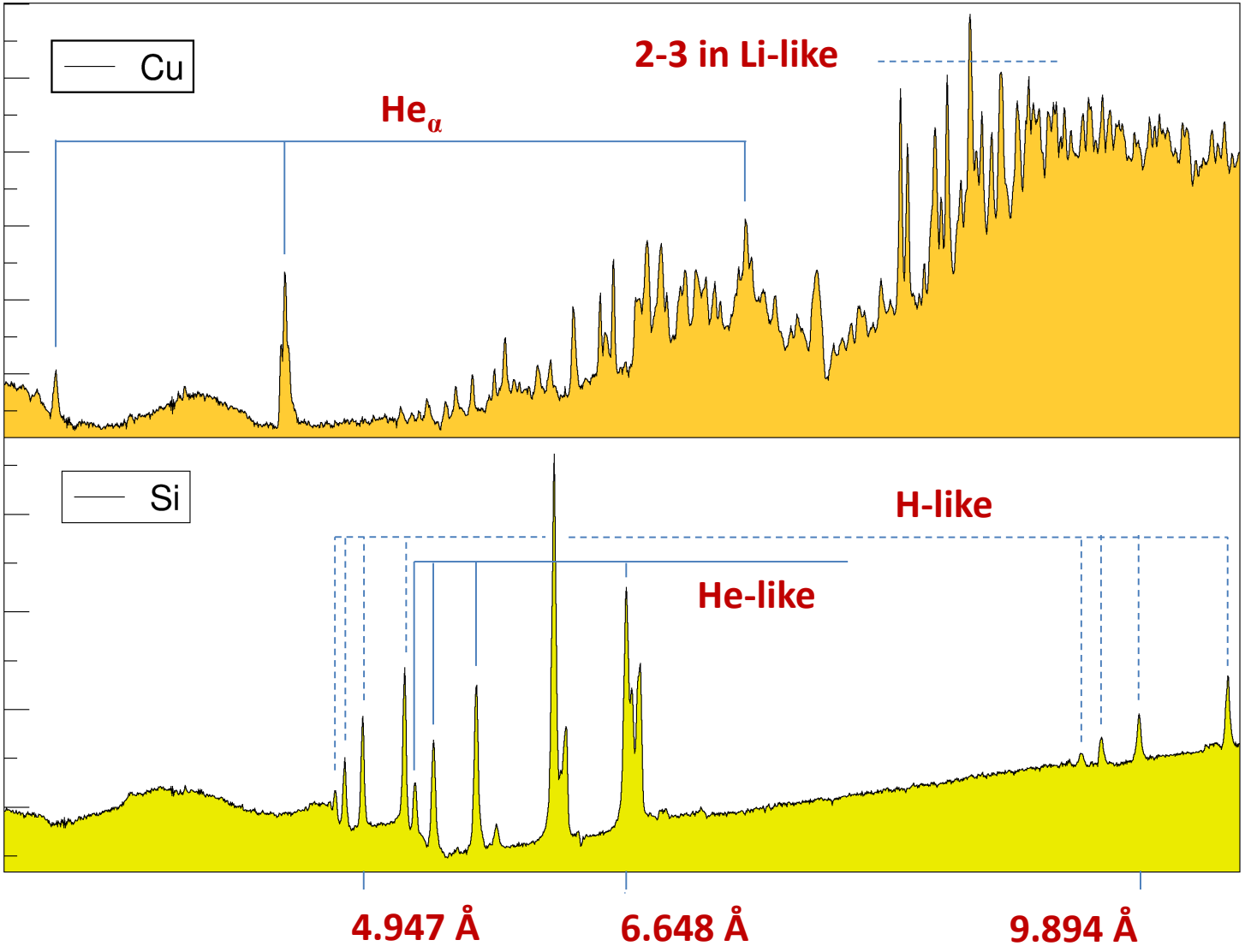
n= 1 2 3 4 5

Spectral lines of He like Fe plus adjacent satellites, observed in multiple orders of reflection

The rest of the spectrum consist mainly of the transitions in Li-like iron

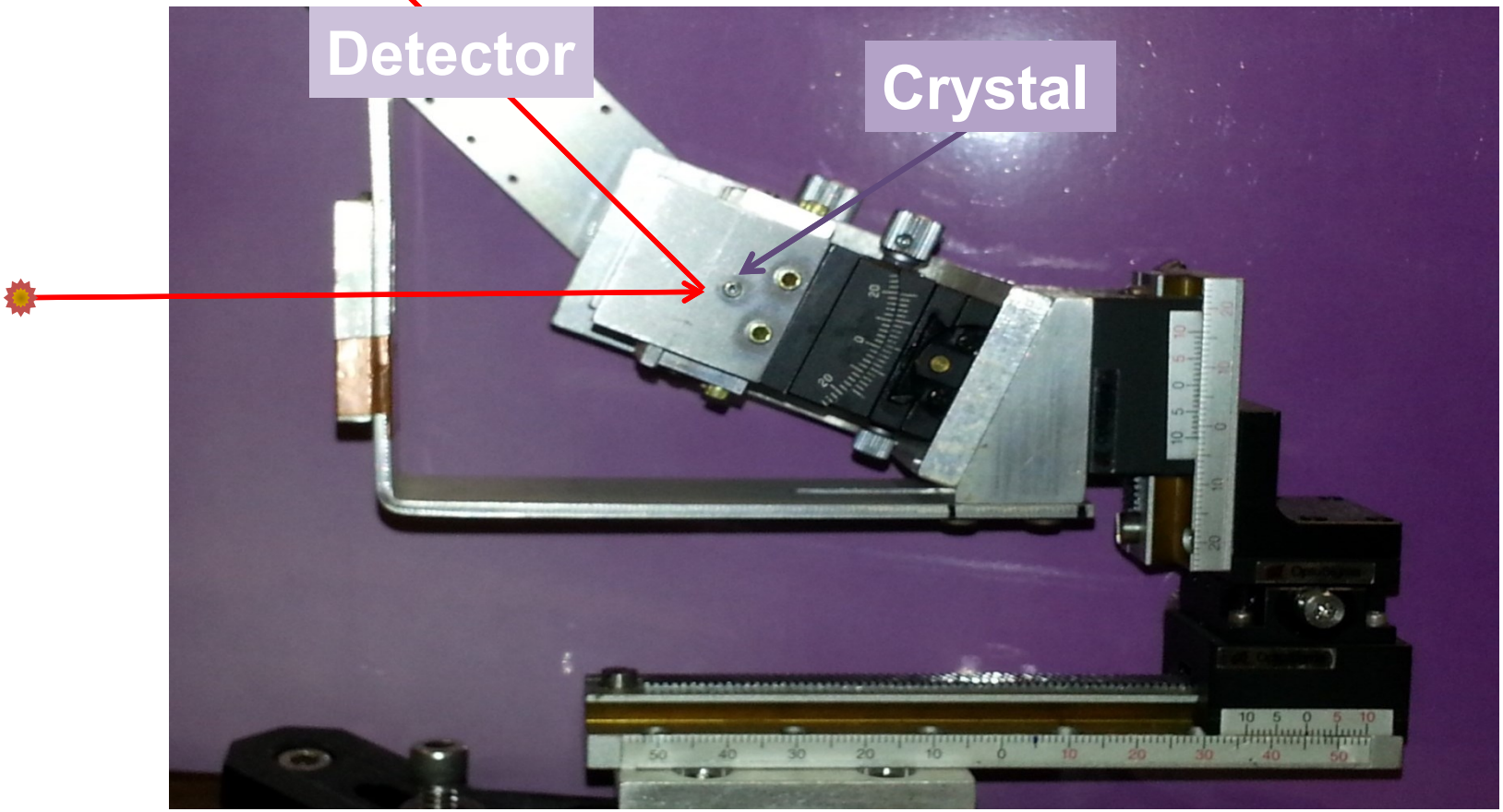
Kapton filter helps to separate high order, higher energy X-rays from the softer ones

Cu and Si spectra

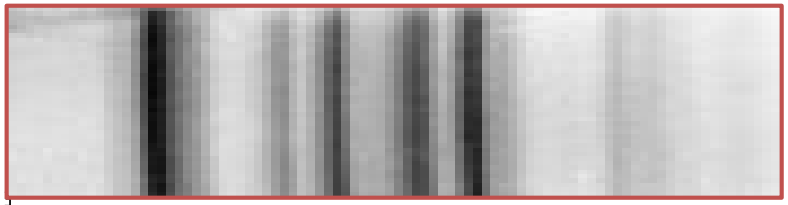


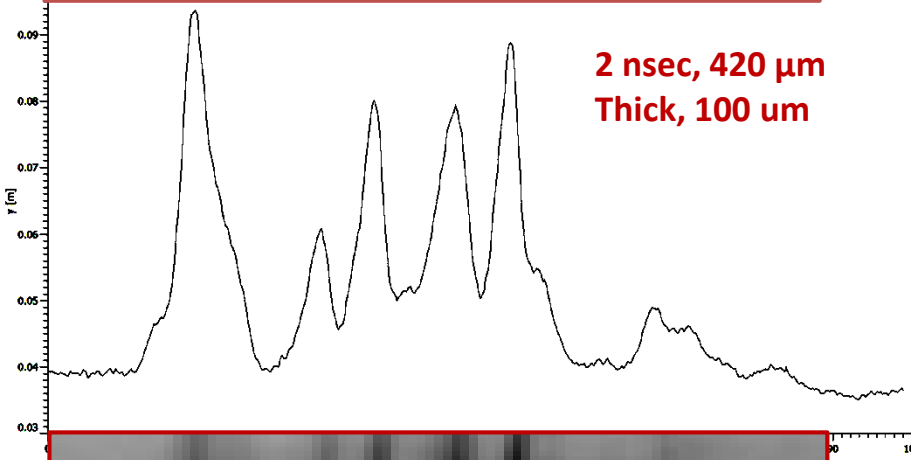
Spherical crystal spectrometer

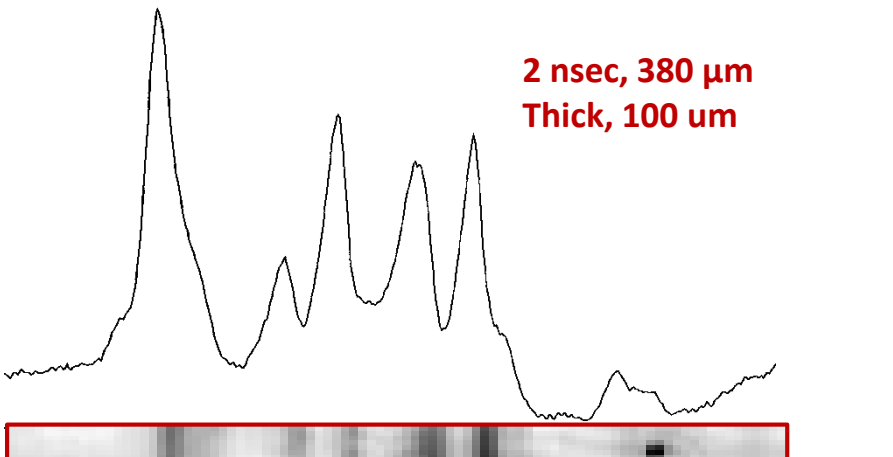
Quartz 223, 2d=2.024Å
λ/Δλ > 2000

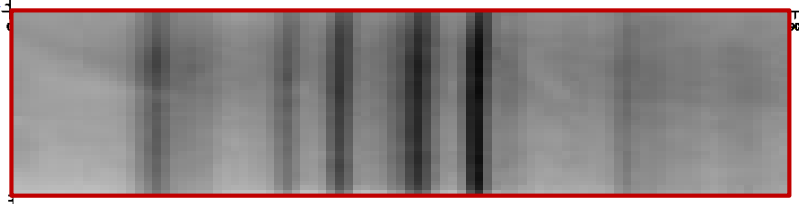


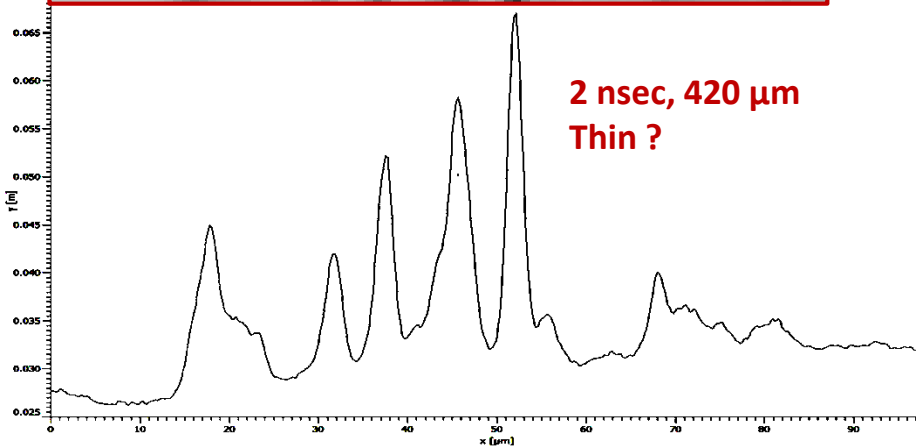
He-like spectra of iron from focusing spectrometer

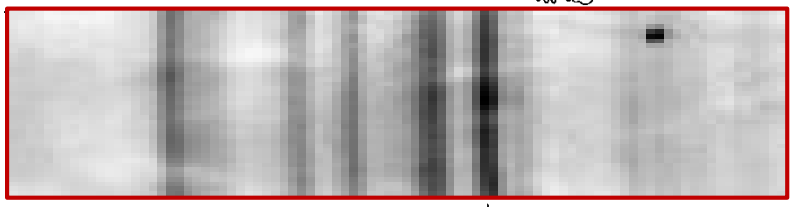


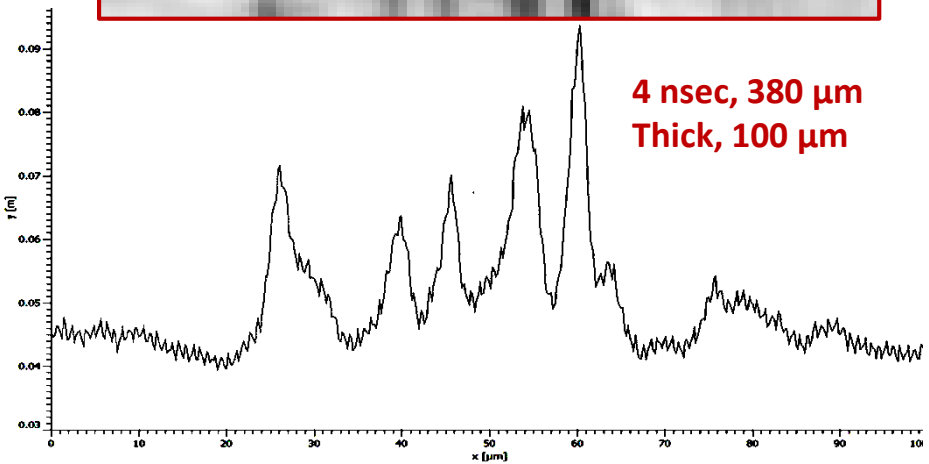




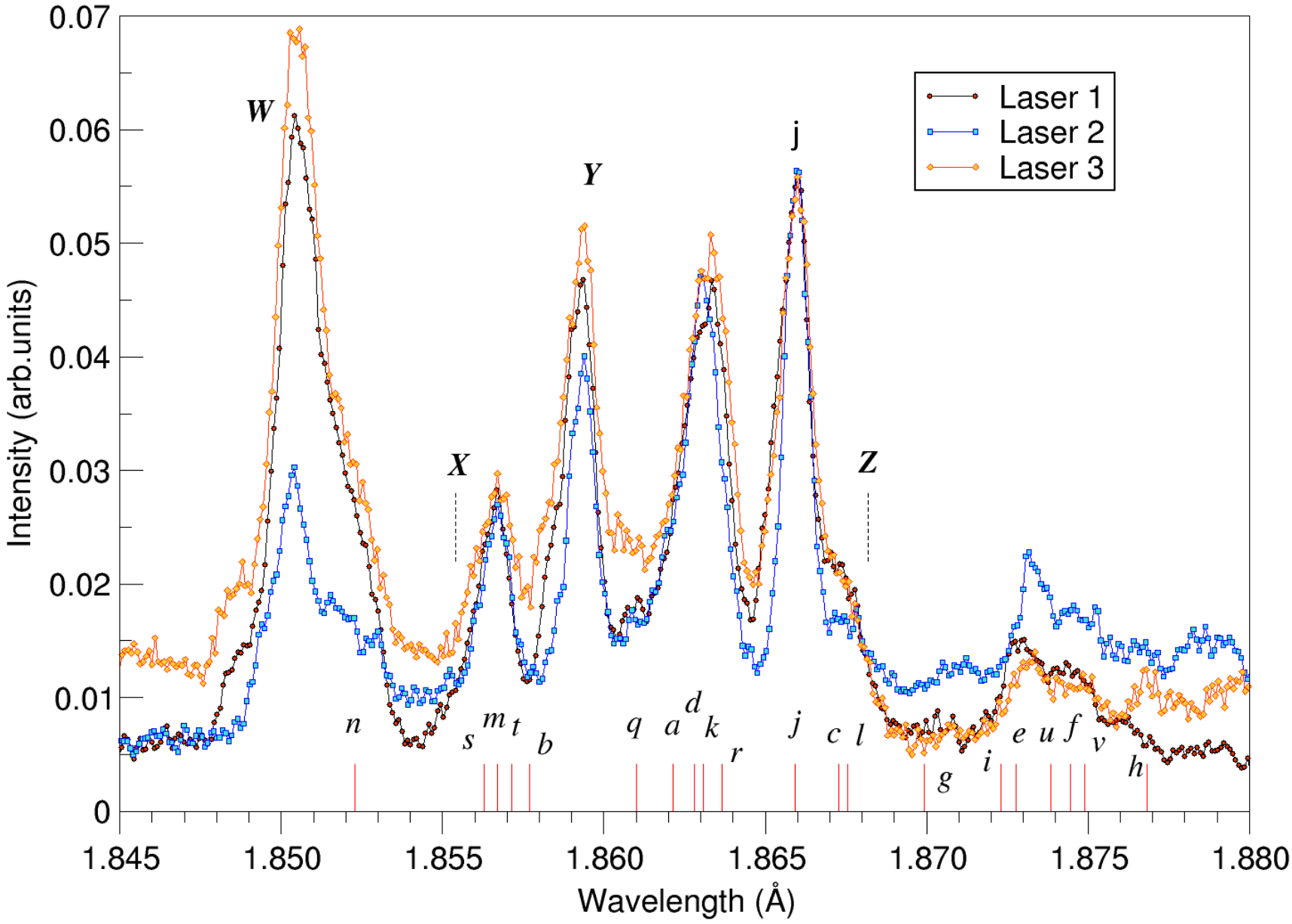




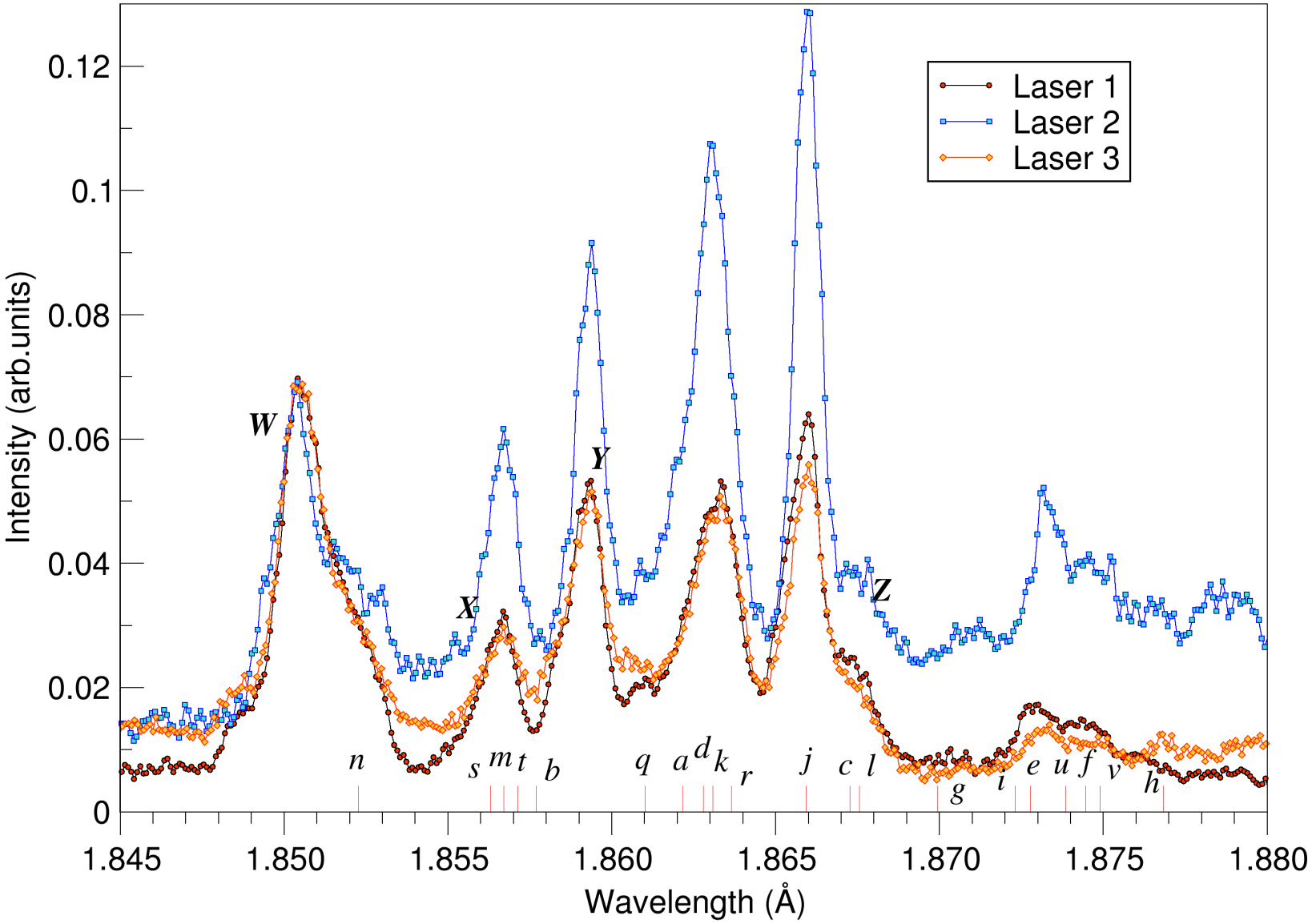




Nike spectra: normalized to j [Li] satellite



Nike spectra: normalized to W resonance line



Collisional-radiative modeling
from atomic structure to synthetic spectrum

Flexible Atomic Code
(Gu, 2003)

- Relativistic model potential w/ some QED
- Level energies
- Radiative and autoionization probabilities
- Collisional cross sections
- Cross sections fit and databased

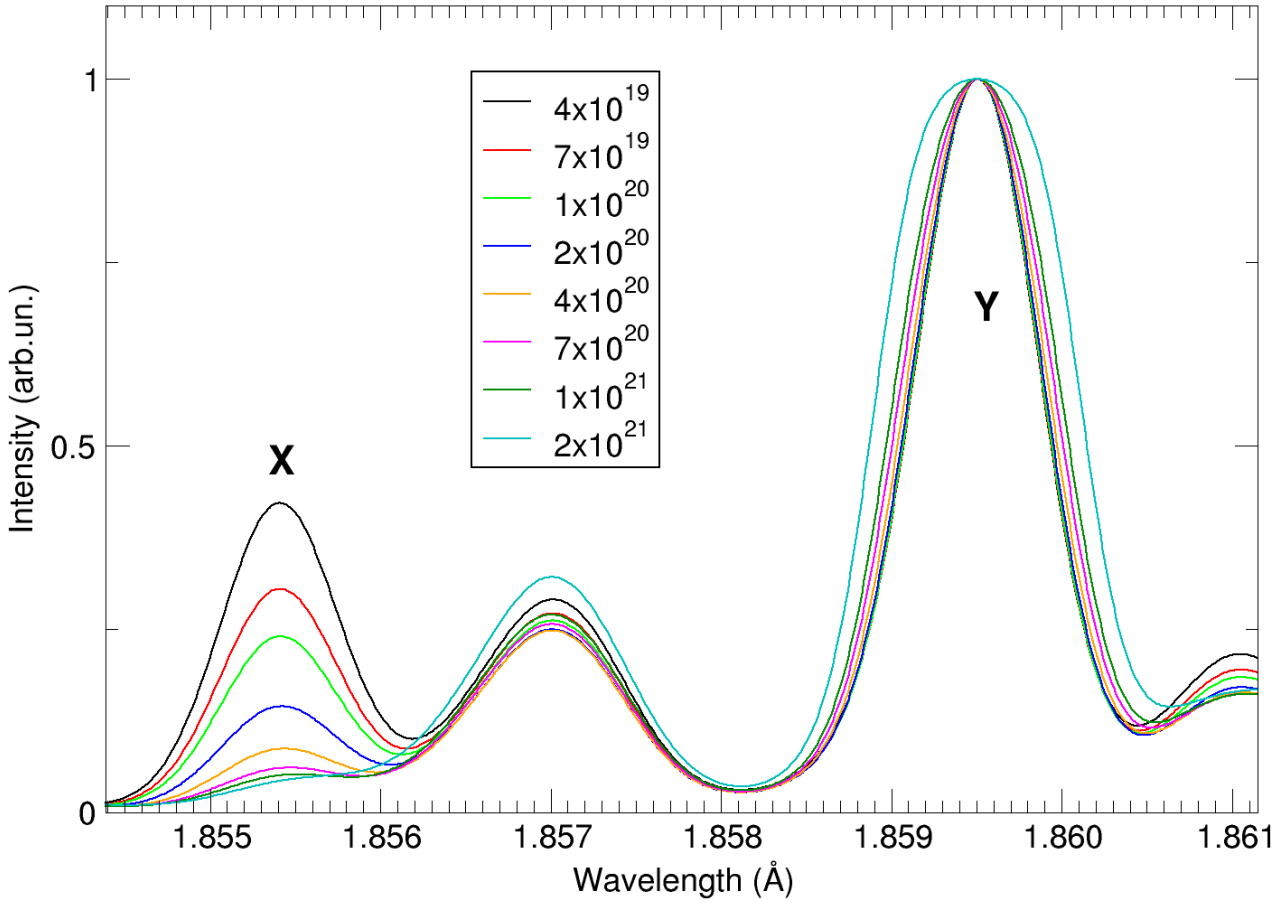
Precise wavelengths of Li-like satellites:
Yerokhin & Surzhikov, 2012

NOMAD
(Ralchenko & Maron, 2001)

- Time-dependent collisional-radiative code for non-Maxwellian plasmas
  - charge exchange, laser pumping, parabolic states…etc.
- Steady state (for the present case)
- Opacity (escape factor for populations, radiative transfer for spectra)
- Ionization Potential lowering
- From [Be] ions to bare nuclei were included ~**2,000** levels

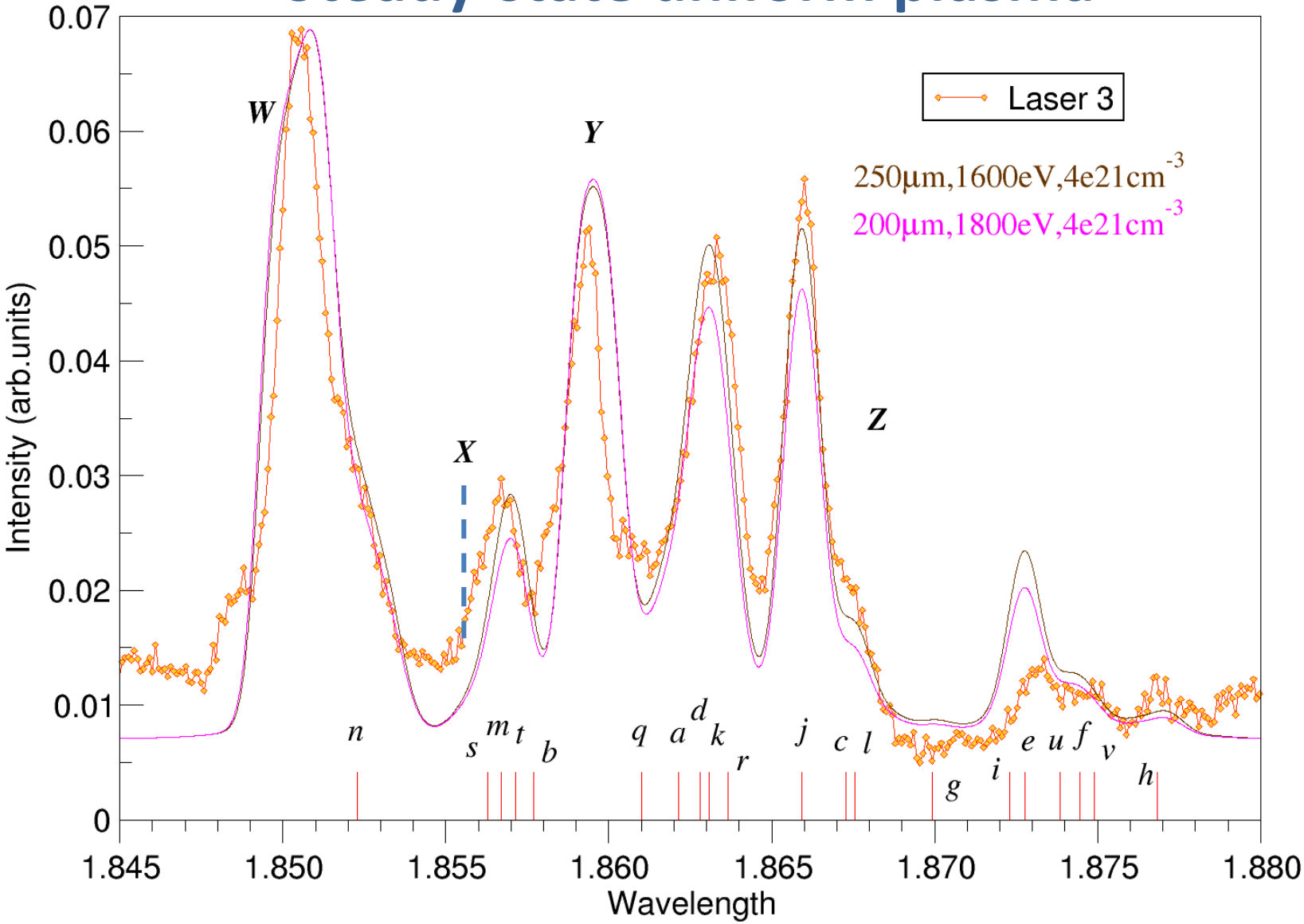
Synthetic Spectrum

Diagnostic tool : Forbidden line $X=1s^2\ ^1S_0\text{-}1s2p\ ^3P_2$ to intercombination line $Y=1s^2\ ^1S_0\text{-}1s2p\ ^3P_1$ ratio as a function of electron density at 1800 eV and r=0.02 cm



If we don't see forbidden line we are looking at the plasma with higher density

First attempt of Nike plasma diagnostics: Steady-state uniform plasma

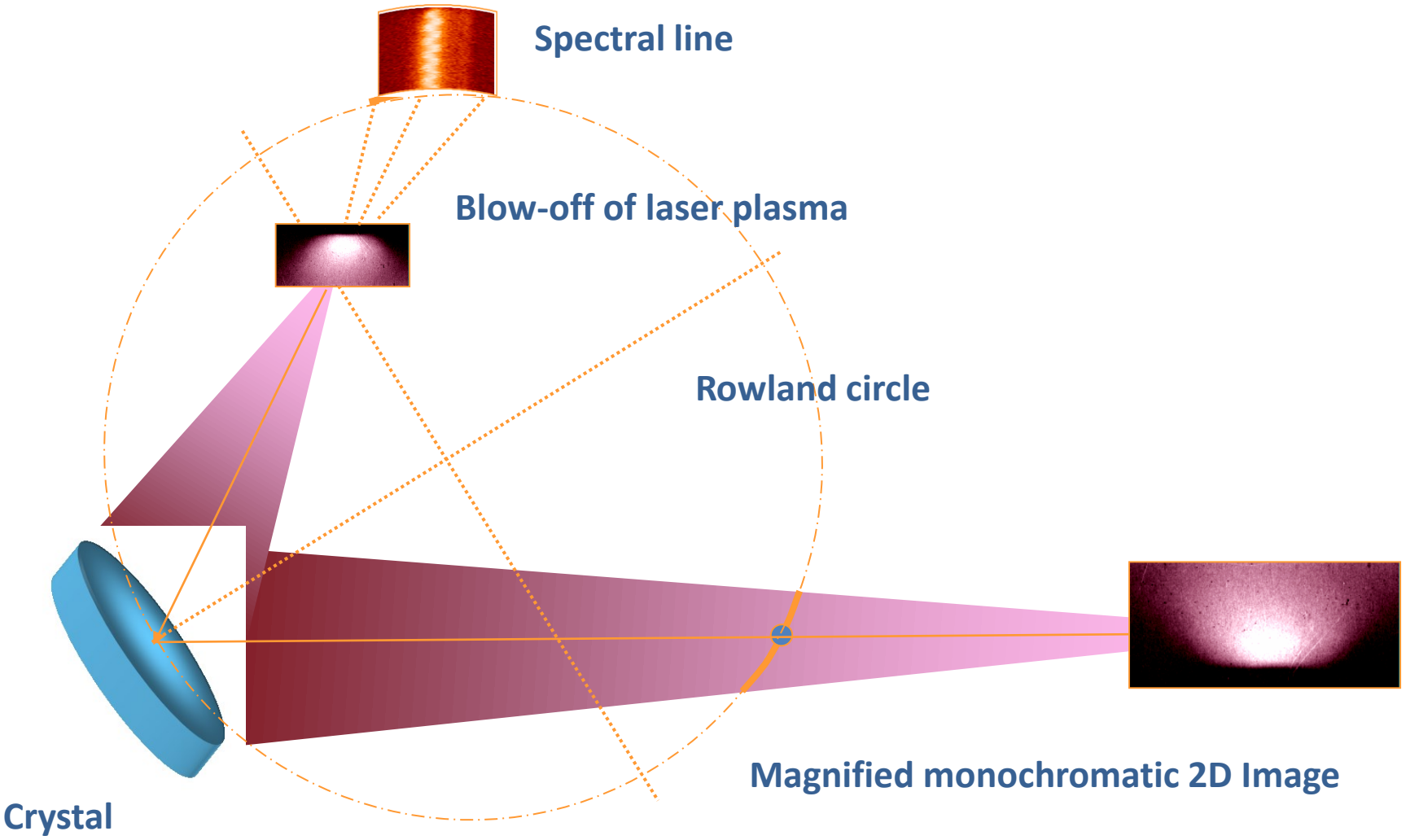


The measured spectra will serve as a benchmark at the 9th Non-LTE Code Comparison Workshop, Dec 2015, Paris, France

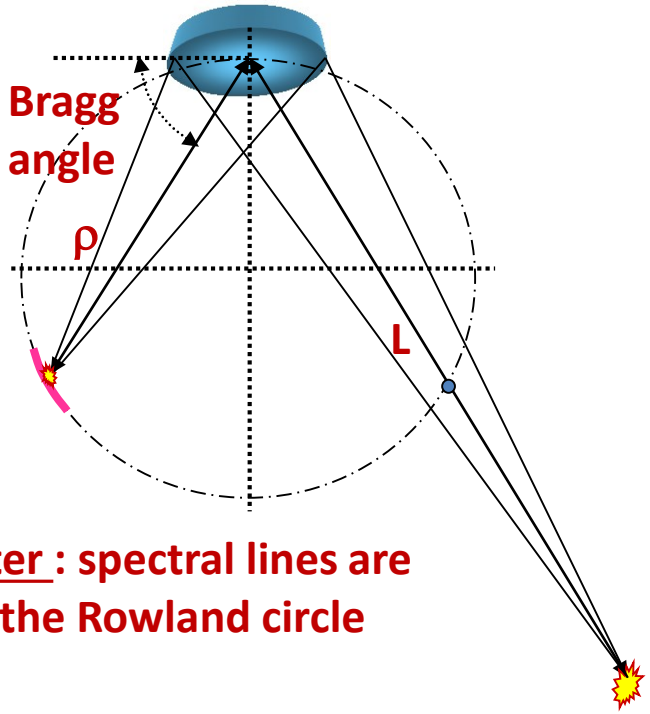
Codes: detailed level accounting, detailed configuration accounting, superconfigurations, hydrogenic, averaged atom…

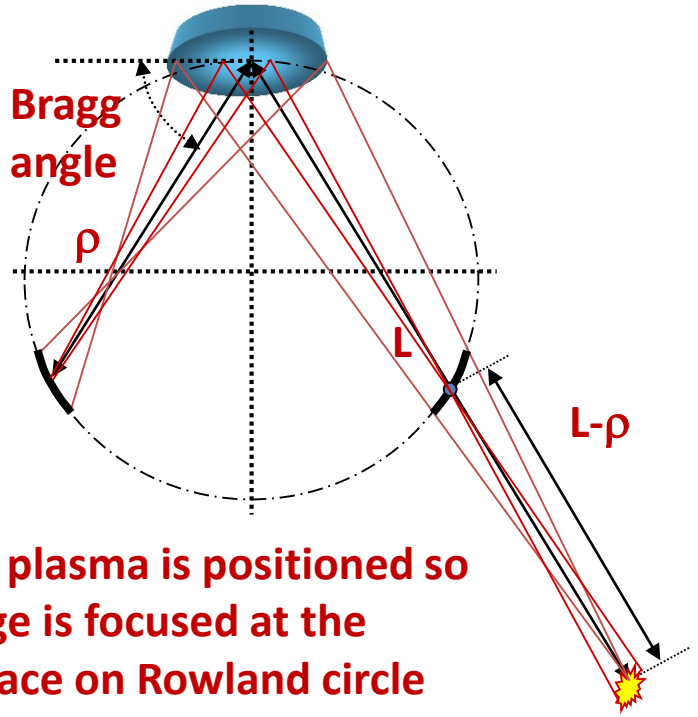
Expected participants: LANL, Sandia, LLNL, NIST, UK, France, Japan, Spain…

2D-imaging with spherically bent crystal



1D-imaging spectroscopy with spherically bent crystal

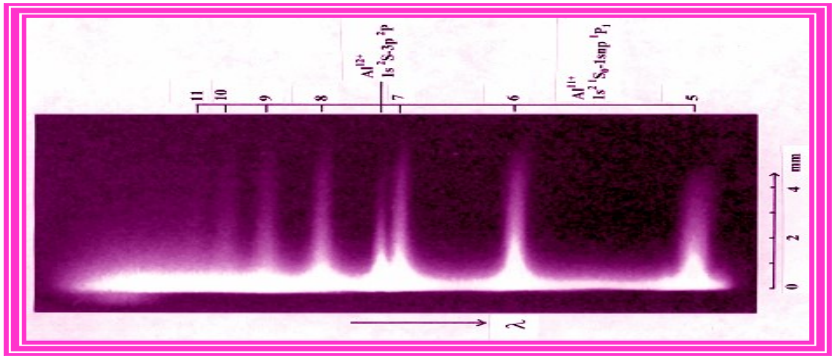




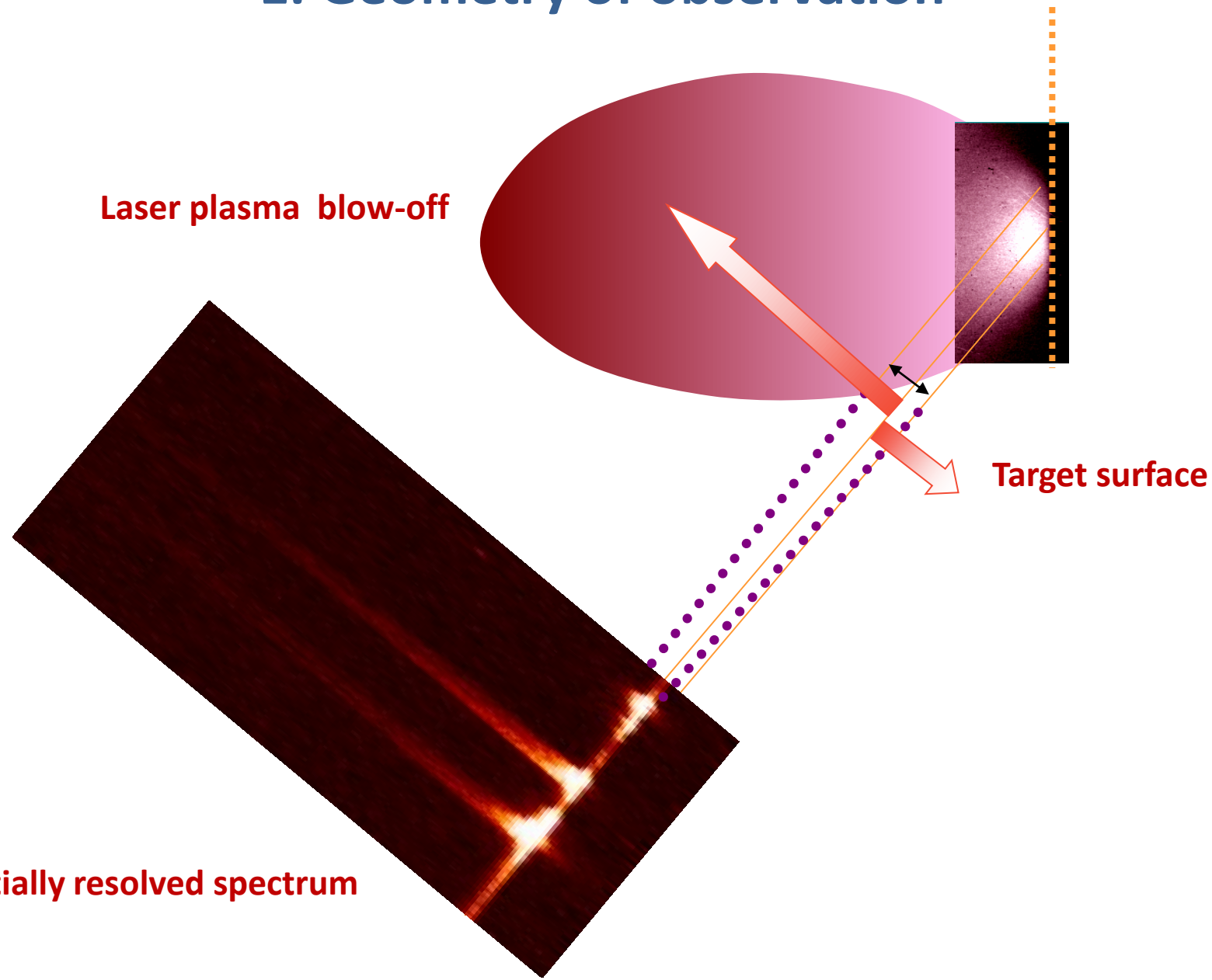
Spectrometer : spectral lines are focused on the Rowland circle

Mirror : plasma is positioned so it's image is focused at the same place on Rowland circle

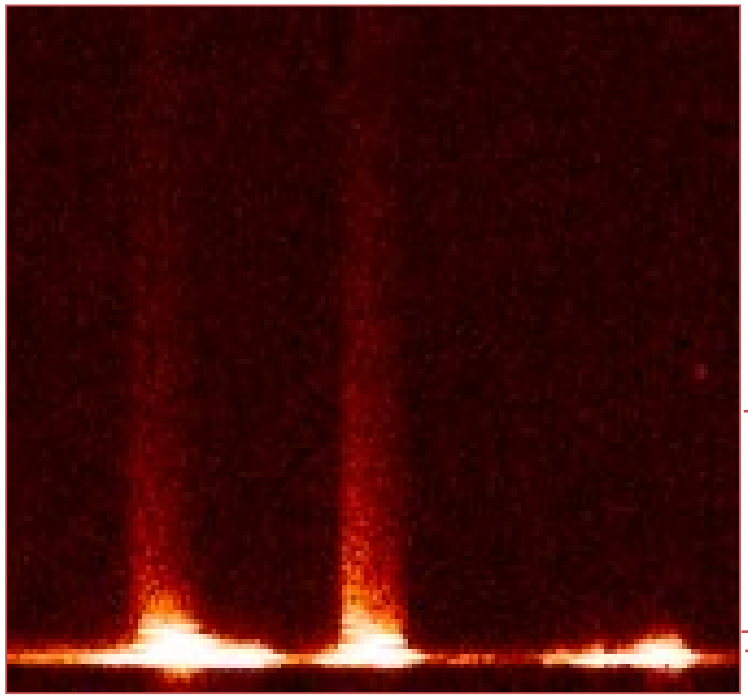
Result : demagnified 1D spatially resolved spectrum

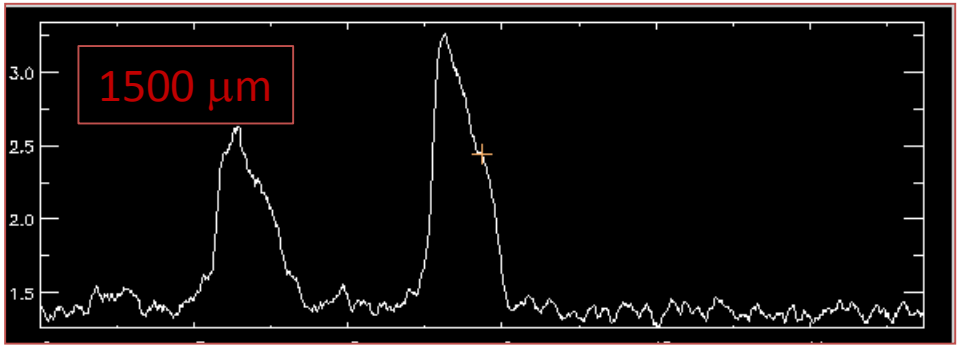


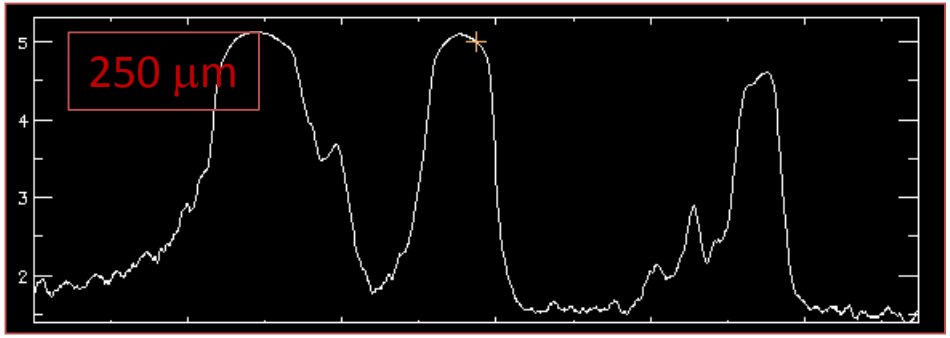
Example: He-like Silicon
1. Geometry of observation

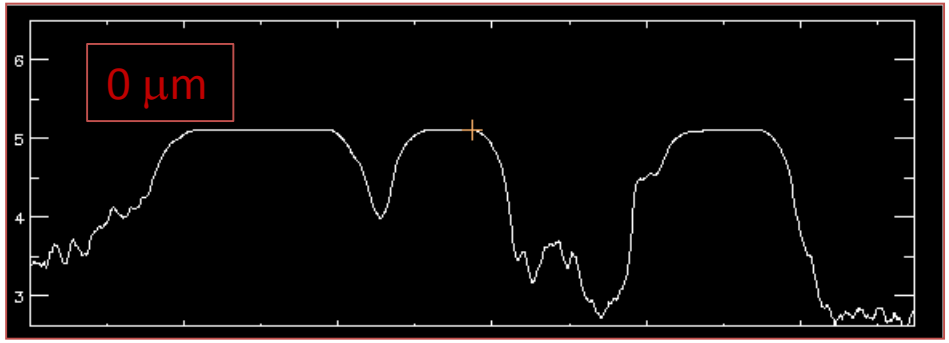


2. Si He-like spectrum spatially resolved

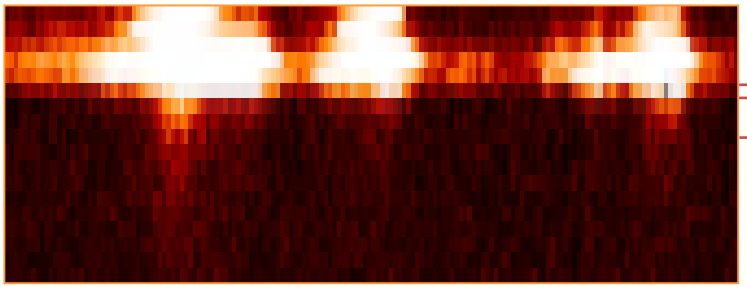


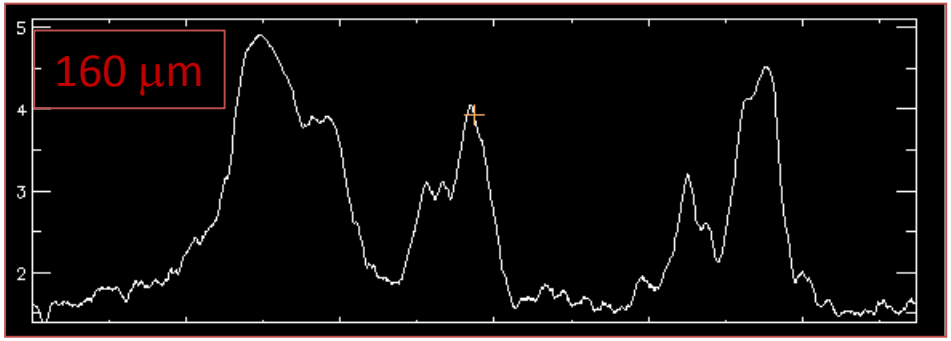


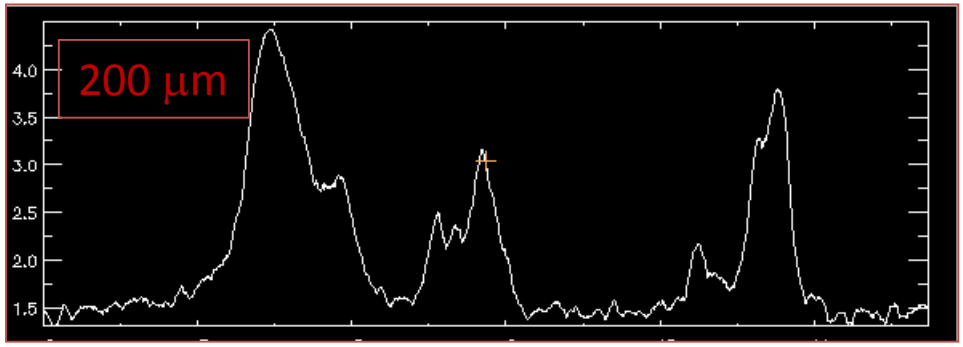


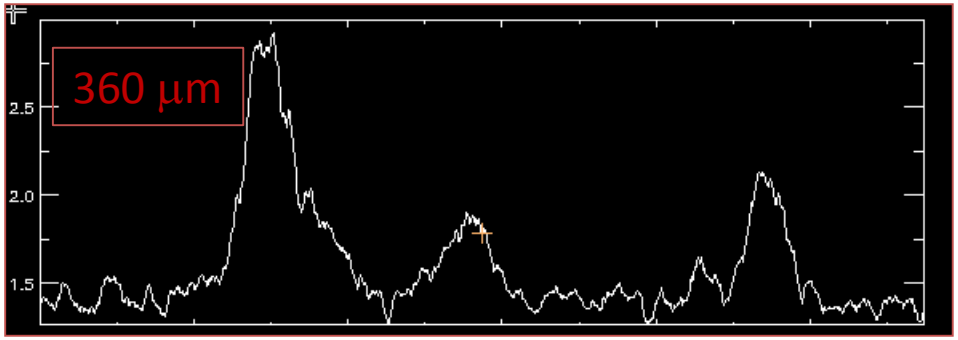


3. Si He-like spectrum spatially resolved









Conclusion

- The goal of this study of Fe X-ray spectra is to test and demonstrate the diagnostic capabilities available on Nike laser.
- For this purpose two high-resolution x-ray spectrometers have been added to the Nike diagnostic suite.
- One is a survey instrument covering the spectral range from 0.5 to 19.5 angstroms, and the other is an imaging spectrometer using a spherically curved crystal. The survey instrument allows simultaneous high-spectral-resolution observations of both K- and L-spectra of highly-charged ions with nuclear charge Z=20-30+.
- The imaging spectrometer provides even more detailed spectra within a narrower variable spectral band with a substantially higher efficiency, spectral and spatial resolution.
- Nike shots taken with intensity of 2×10^{14} W/cm^2 confirmed presence of strong spectral lines from He-like ions along with multiple satellite lines originating from the lower stages of ionization. High-quality n=2-n=3 spectra from L-shell ions of the same elements were also observed.
- Collisional-radiative simulations with the NOMAD code were successfully used to model the recorded spectra.
- Higher Z spectra with spatial resolution are planned.

*Supported by DOE NNSA.