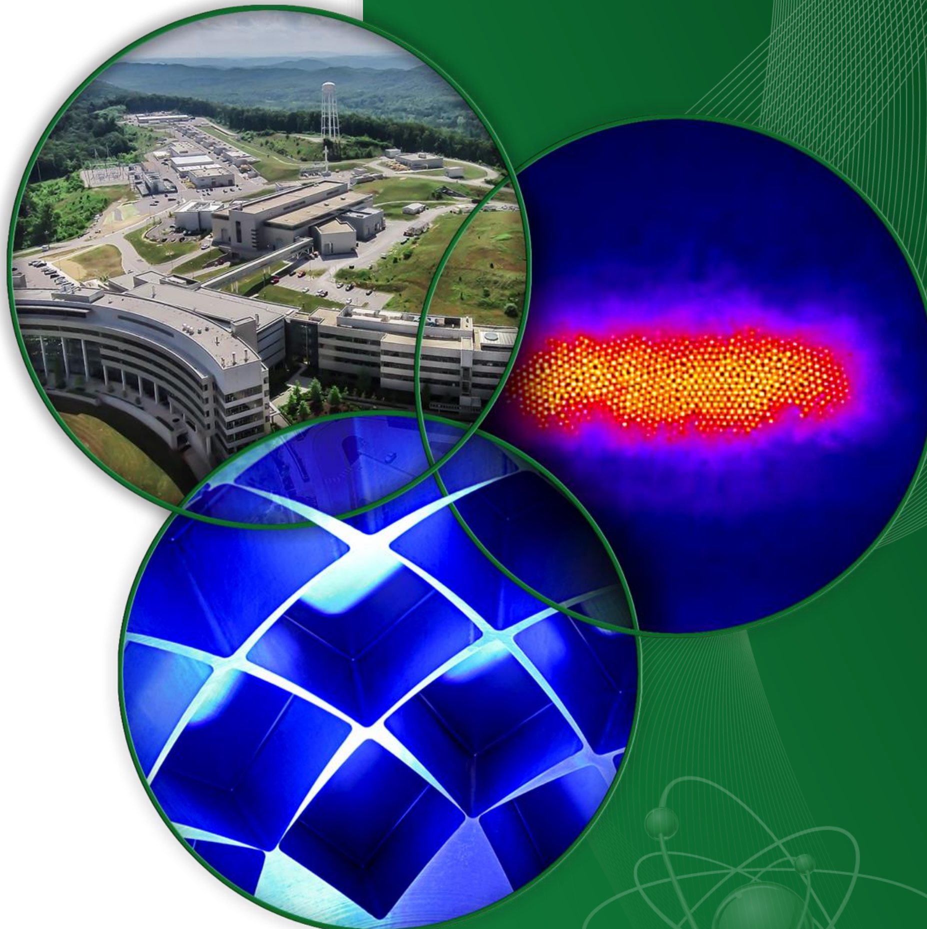
Laser Stripping

Sarah Cousineau

SNS AAC Review

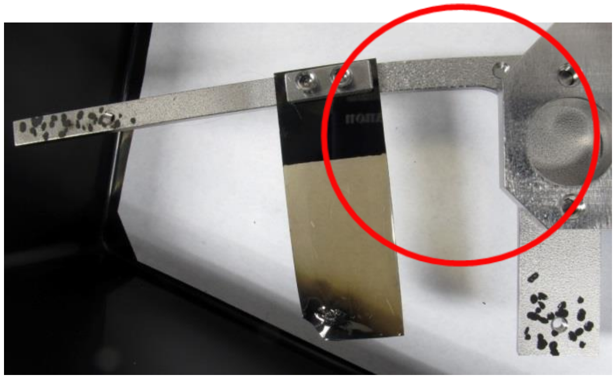
March 24-25, 2015



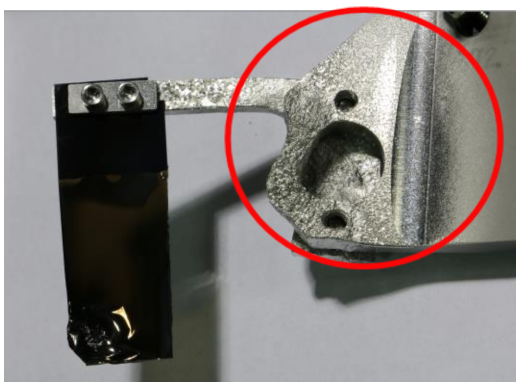
ORNL is managed by UT-Battelle
for the US Department of Energy

Motivation

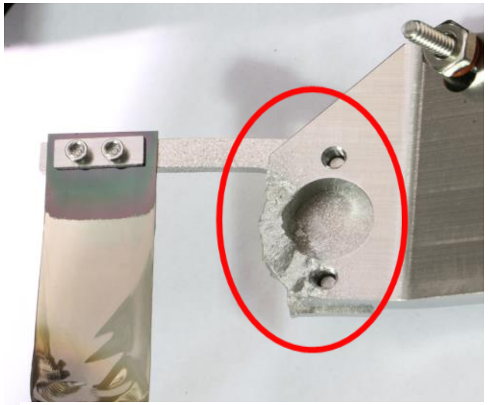
- Foil bracket damage increasing exponentially with higher beam powers.
- Injection is hottest area in the accelerator 500 – 800 mrem/h (@ 30 cm) due to foil scattering.



#1839, used for 1.1 – 1.2 MW for a few weeks, then 1.4 MW demonstration for a few minutes, and then 1.3 MW for ~32 hours.

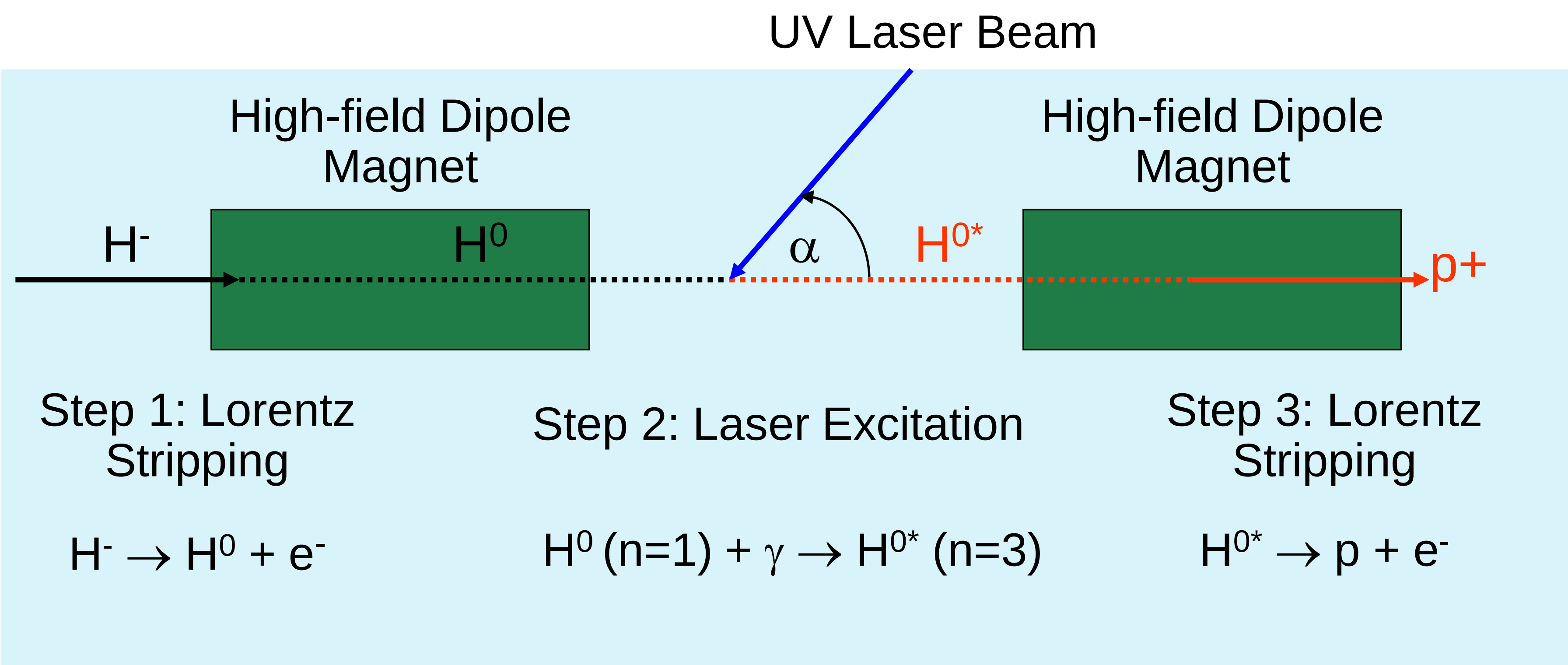


#1872, up to 1.4 MW. 3 months at 1.1 to 1.4 MW.



BW-18. ~24 days at ~1.2 MW

Review of 2006 Laser Stripping Experiment



- Demonstrated at SNS for a 6 ns H^- beam.
- **Straightforward scaling from 6 ns to full duty cycle requires 600 kW average UV laser power. Not achievable.**

The 10 μs Stripping Project

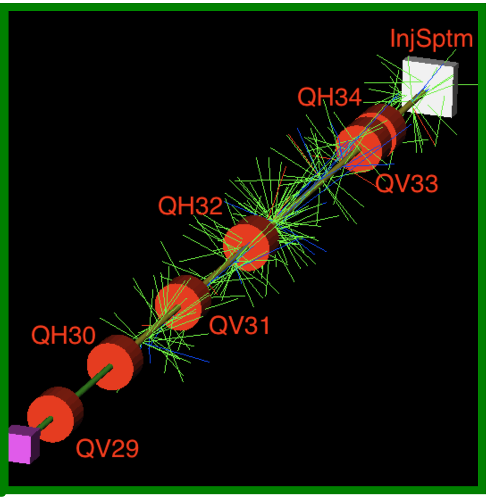
Goal: Demonstrate H^- laser-assisted stripping with 90% efficiency for a ~μs long 1 GeV H^- beam.

Supported by DOE HEP Grant, $825K (DE-FG02-13ER41967):

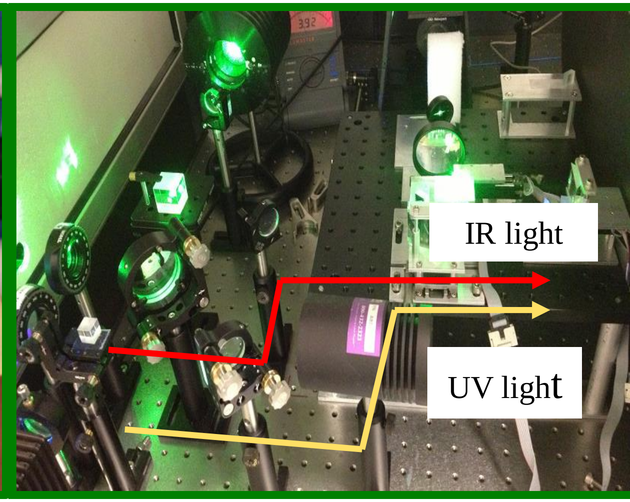
- Three institution collaboration:
  - University of Tennessee (primary)
  - Spallation Neutron Source
  - Fermilab
- Provides large amount of educational funding.
- Time scale: 3 Years. Entering year 3 on April 1, 2015.
- Preparation efforts focus on three areas:
  1. Hardware configuration
  2. laser parameters
  3. ion beam optics.

Educational Component of Grant

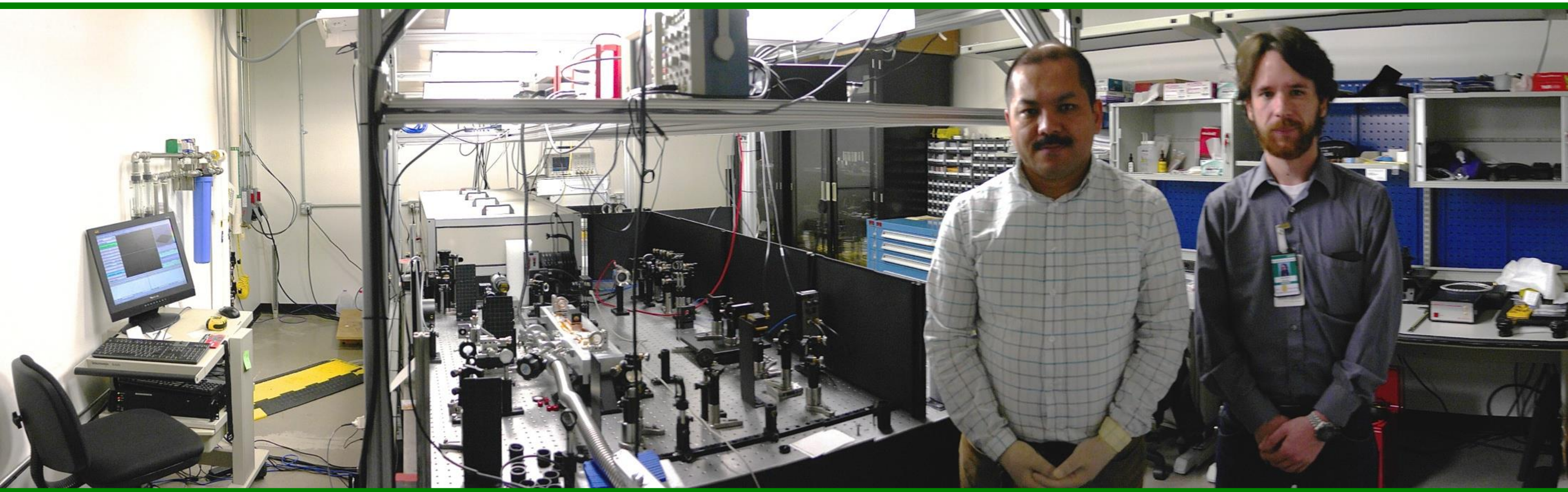
Undergraduate N. Luttrell
(2 summers)



Undergraduate F. Garcia
(2 summers)



Postdoc A. Rakhman (left), Graduate Student Michael Baude (right)



UT/SNS Accelerator Physics Program

- Partnership to grow an accelerator physics educational program at UT.
  - 4 graduate students
    - Michael Baude (laser stripping)
    - Brandon Cathey (ITSF beam dynamics – NSF proposal)
    - Robert Potts (space charge dynamics in ring)
    - Dirk Bartkowski (diagnostics). Graduated 2013
  - 1 to 2 undergraduate interns per summer
  - Research support:
    - SNS
    - DOE HEP (laser stripping)
    - Applied for support from NSF Accelerator Science program (1 postdoc, 1 graduate student, 3 undegraduate).

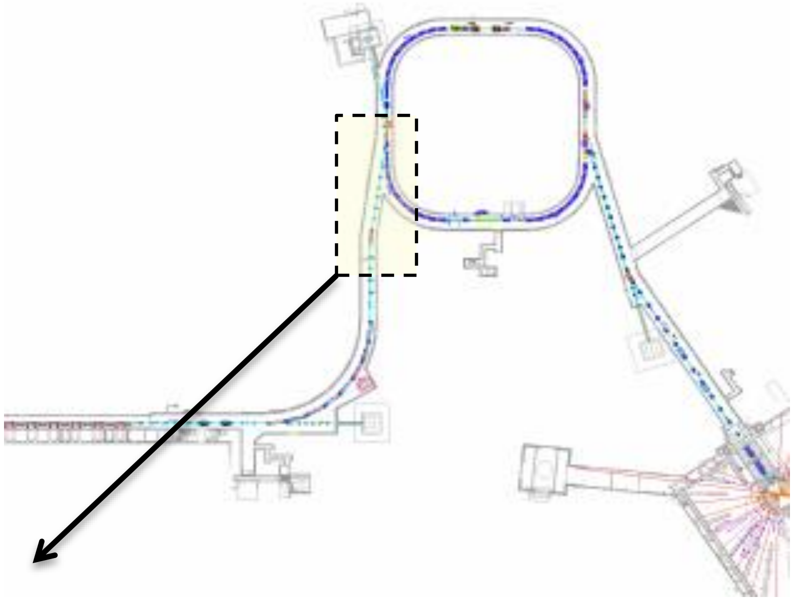
Part I: Experimental Configuration and Hardware Development

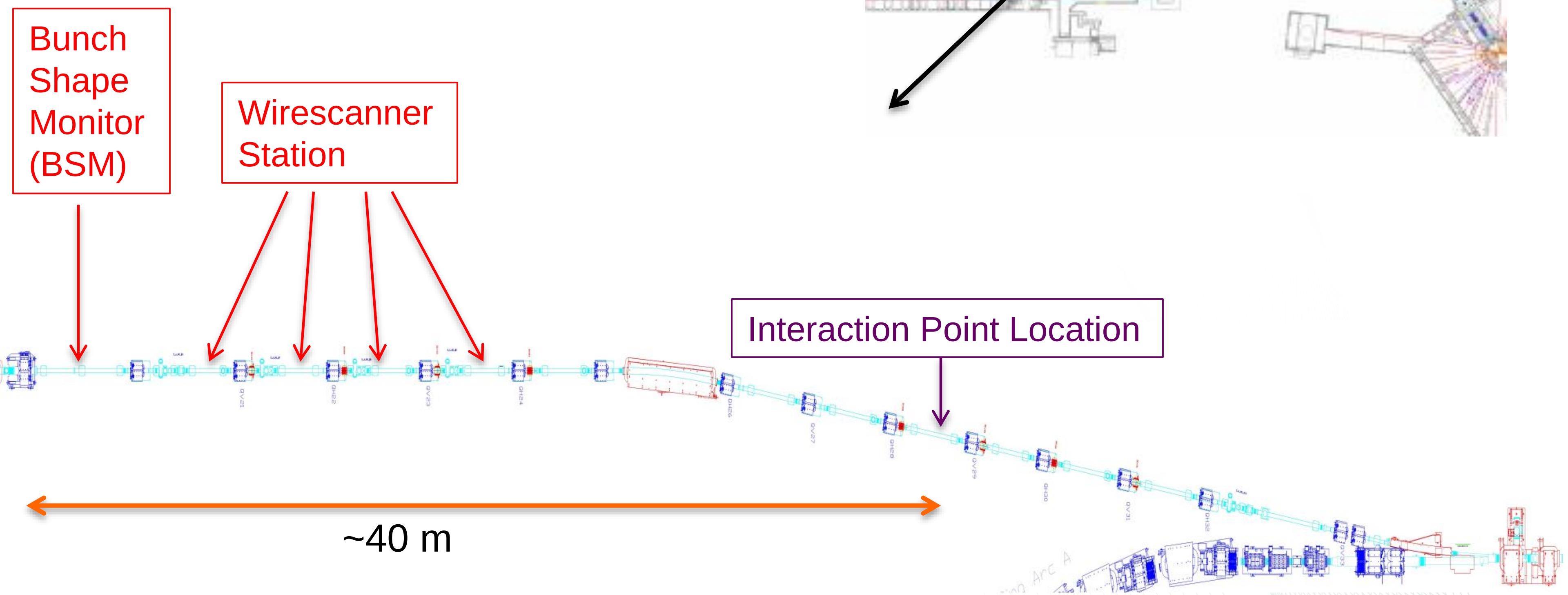
Goals for experimental configuration:

1. Support high-efficiency H^- stripping
2. Protect the laser
3. Provide schedule flexibility for experiment
4. Prevent impact on operations

Interaction Point Location

- IP is downstream of arc in empty drift.
- Has good optics flexibility.
- Diagnostics are 20 – 40 m upstream.
- Low radiation region.
- Reasonable waste beam scenario.



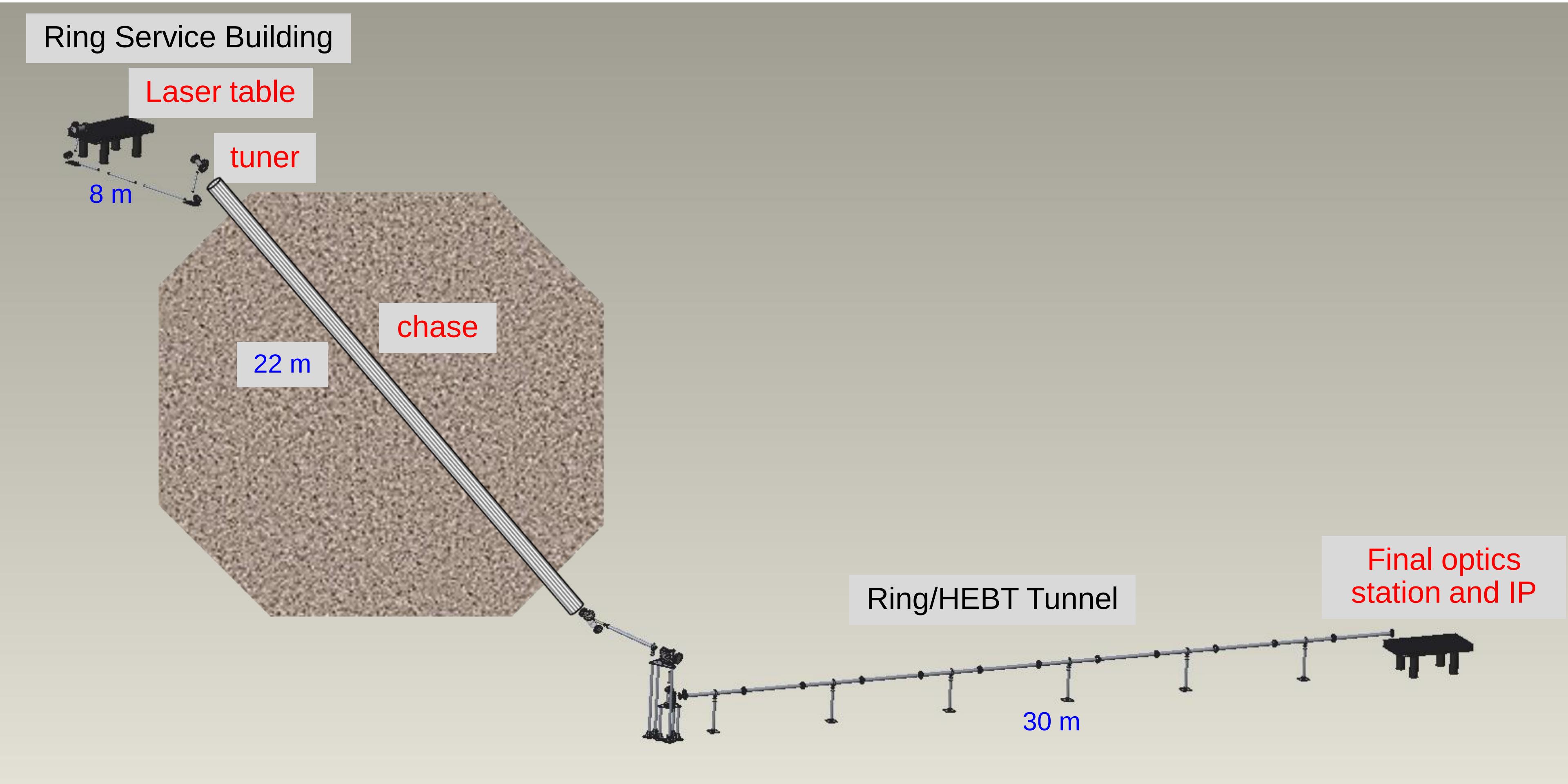


Laser Location and Transport

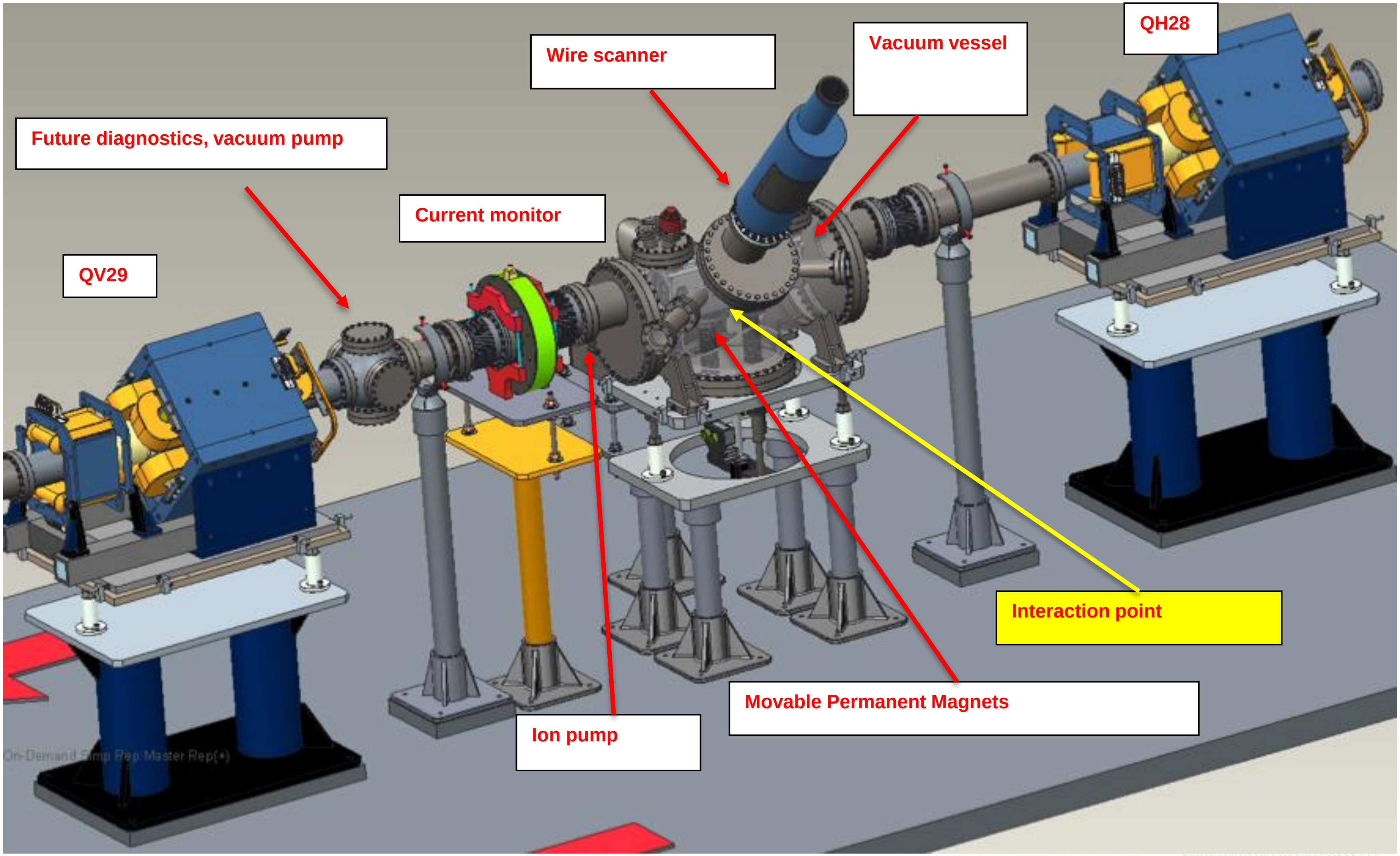
UV laser station located in Ring Service Building, transport ~ 60 m to IP.

- ✓ Protects the laser
- ✓ Provides schedule flexibility

A. Menshov



Experimental Station Final Design

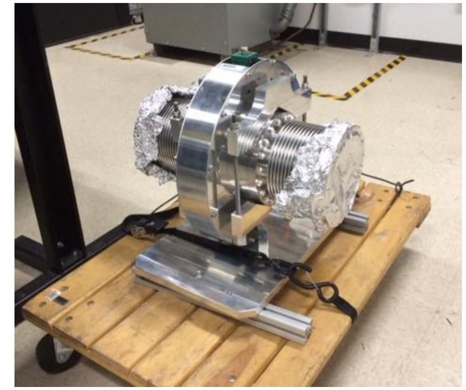


A. Menshov

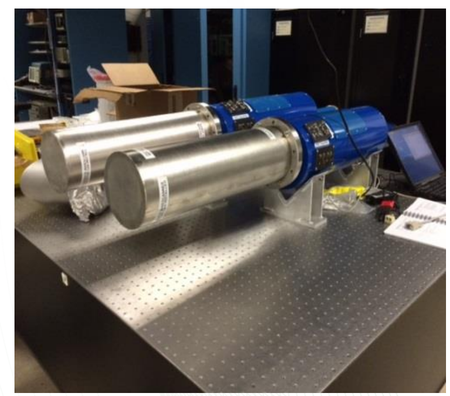
Experimental Station Hardware (Onsite)

Experimental Vessell

BCM



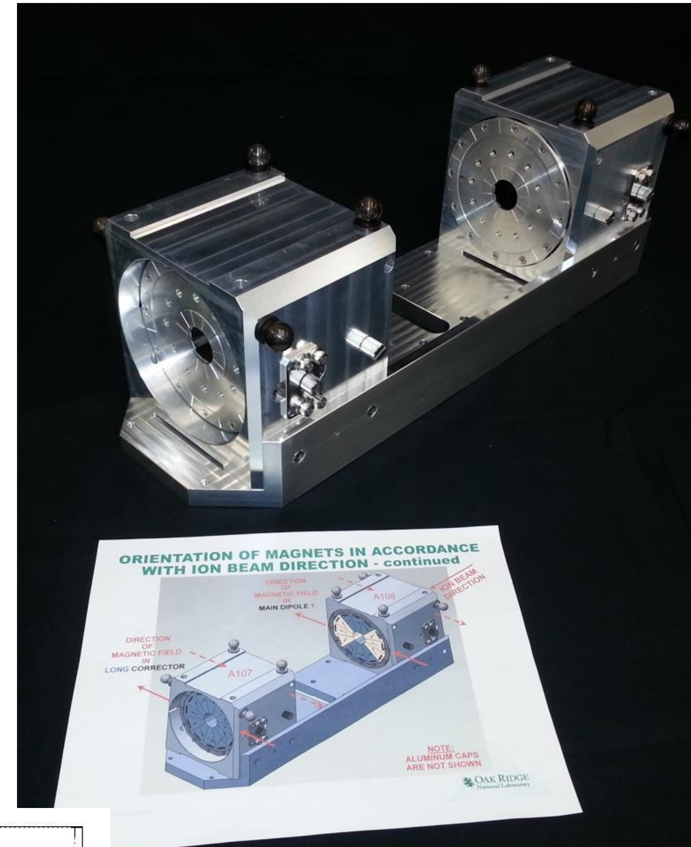
Wirescanners

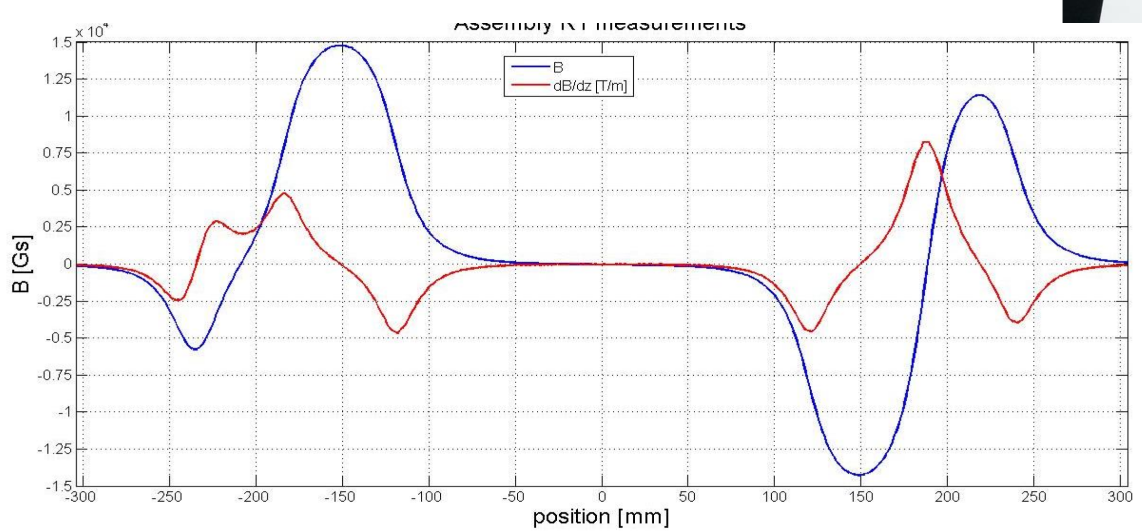


Stripping Magnets Completed

Stripper magnets.

- ✓ Halbach permanent magnet design.
- ✓ High grad B minimizes induced angular spread.
- ✓ Small, light, mounted on actuators for insertion and retraction.
- ✓ Measured field profile after assembly meets all specs.





Part II:
Laser Optics

Goals for UV laser effort:

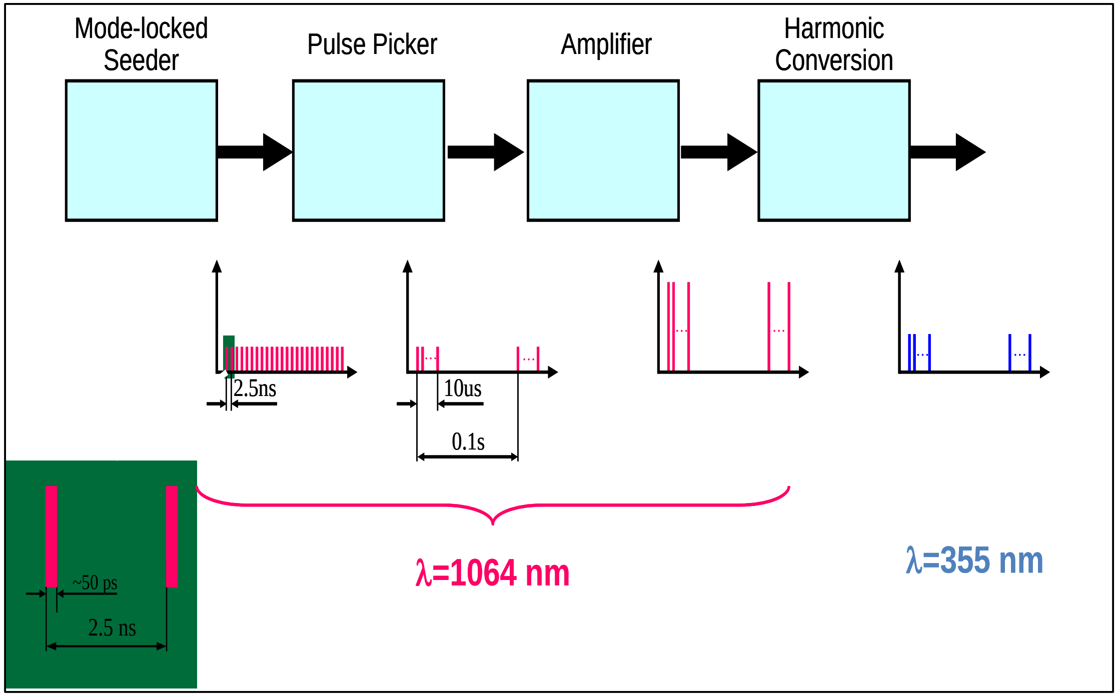
1. Achieve required power and configuration
2. Estimate power loss in transport
3. Estimate/mitigate laser pointing stability

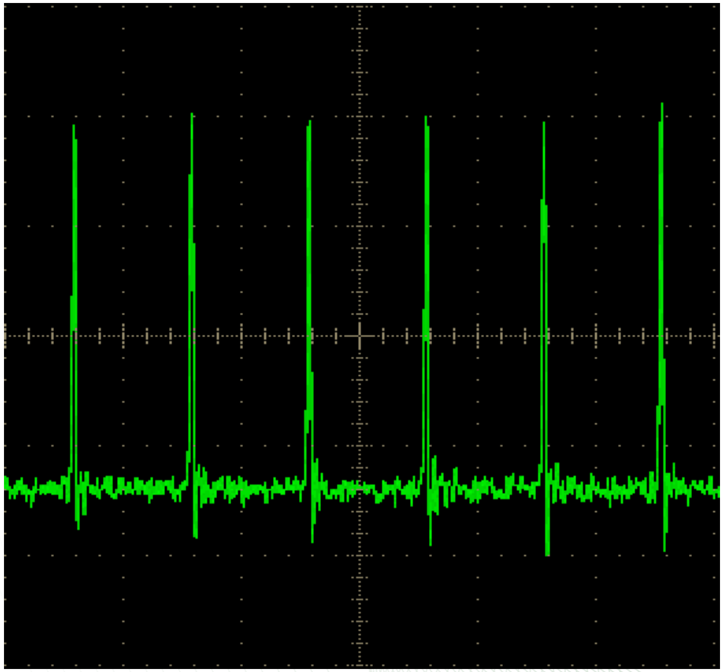
Laser-Ion Beam Temporal Matching

Structure	Time	Frequency
Micropulse	30 – 55 ps	402.5 MHz
Macropulse	5 – 10 us	10 Hz

- **All laser parameters achieved!**
- Power: 1.3 - 3.0 MW (depending on time parameters)

Master oscillator power amplification (MOPA) system





Y. Liu, A. Rakhman

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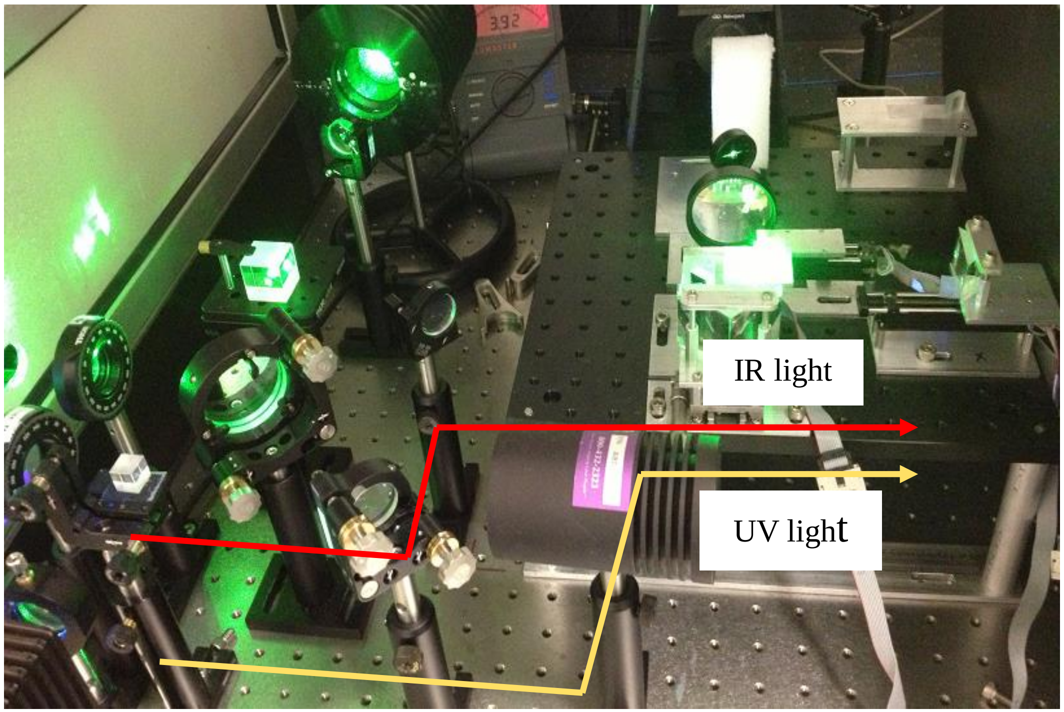
UV Laser Power Measurement

- Detector bandwidth not high enough to measure UV pulse directly.
- Optical correlator built to automate this measurement.



Summer student project 2013

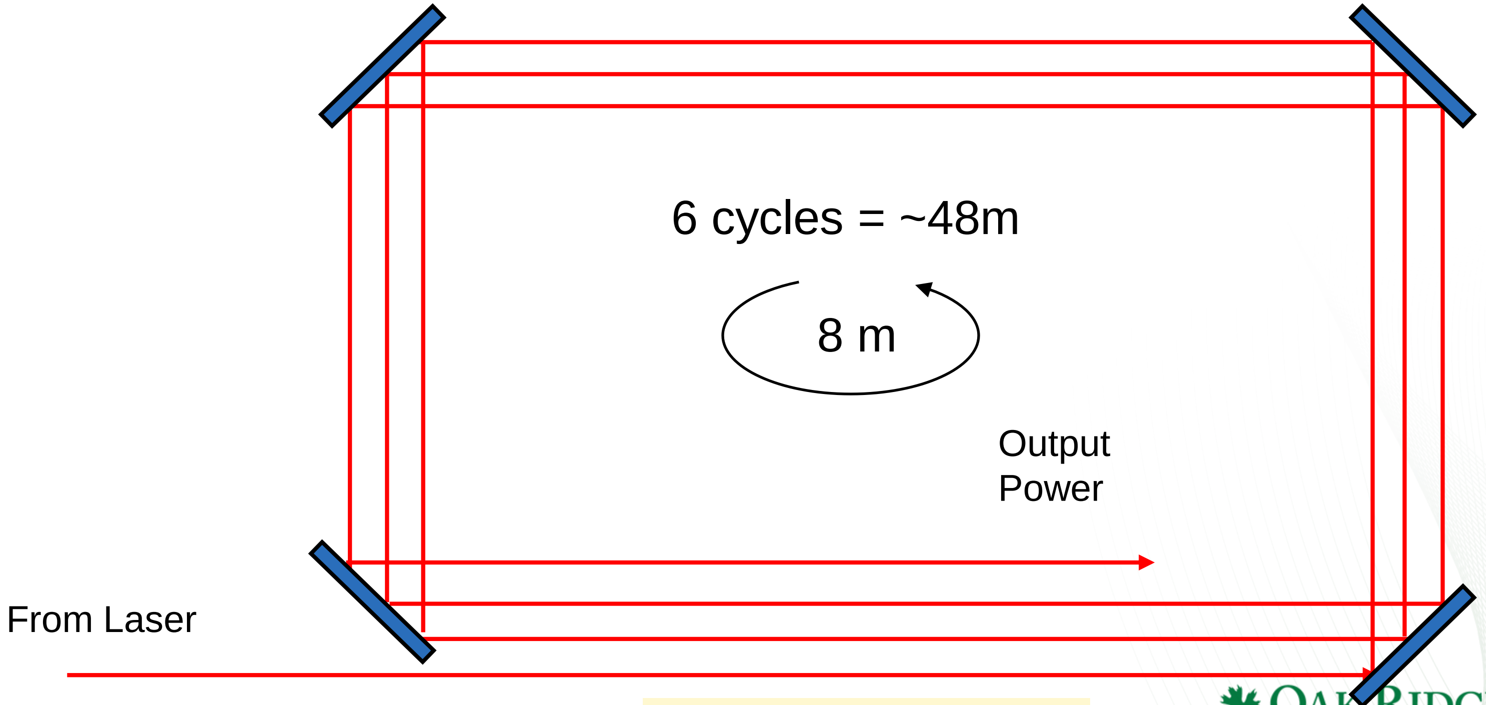
Measured Laser Parameters

UV Peak Power	Pulse structure (micro / macro)
3.0 MW	32 ps / 10 μs
1.3 MW	54 ps / 10 μs
2.1 MW	54 ps / 5 μs

Laser Transport Mock-Ups

- Piezoelectric tuner will stabilize laser against > 1 Hz drift. Higher frequency not expected.
- Mirror losses independently measured to be ≤1%.
- Expect ~ 1/3 power loss (Fresnel diffraction, higher order mode loss).

Conclusion: Remote laser placement is feasible.



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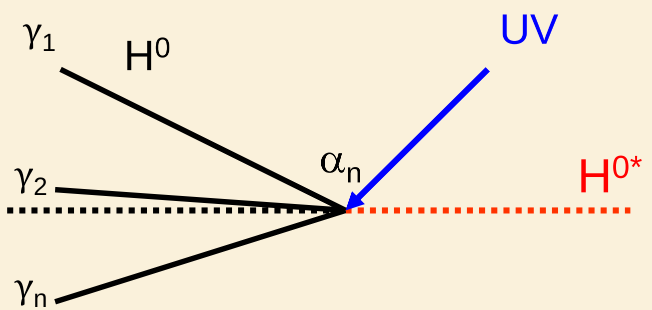
Part III: Ion Beam Optics

Goals for ion beam optics:

1. *Maximize laser-ion beam interaction* by "squeezing" the ion beam.
2. *Minimize the transition excitation frequency spread* by tailoring the dispersion (D,D') and Twiss α.

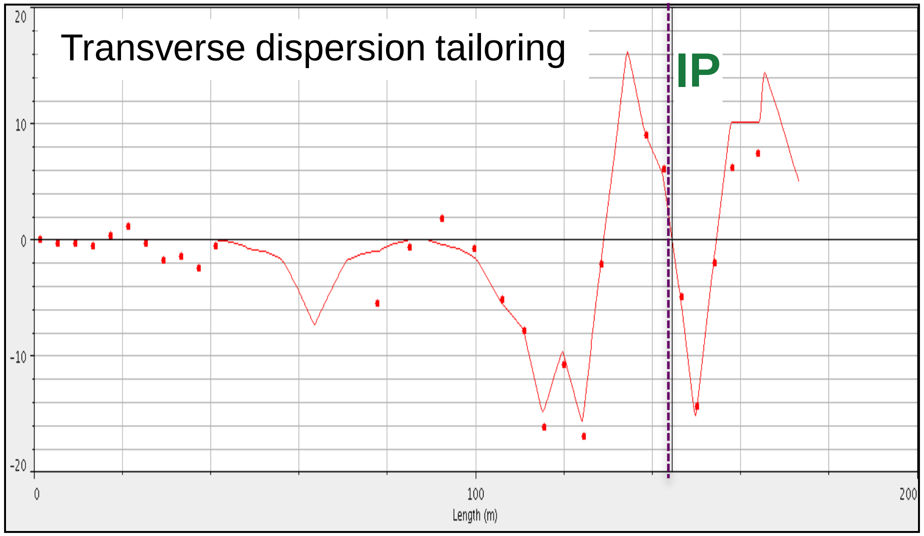
$$f_{\text{rest frame}}(1 \rightarrow 3) = \gamma_n (1 + \beta_n \cos(\alpha_n)) f_{\text{beam frame}}$$

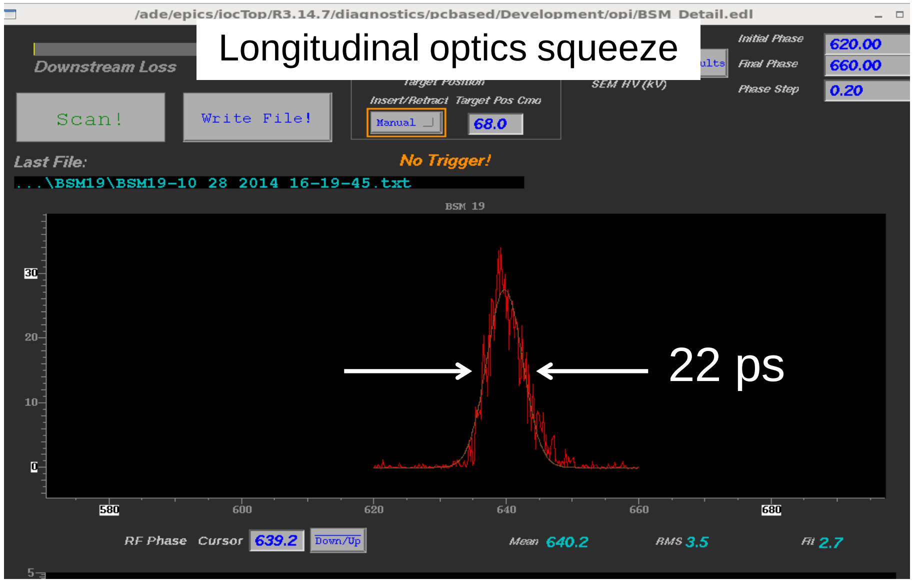
Dispersion Tailoring

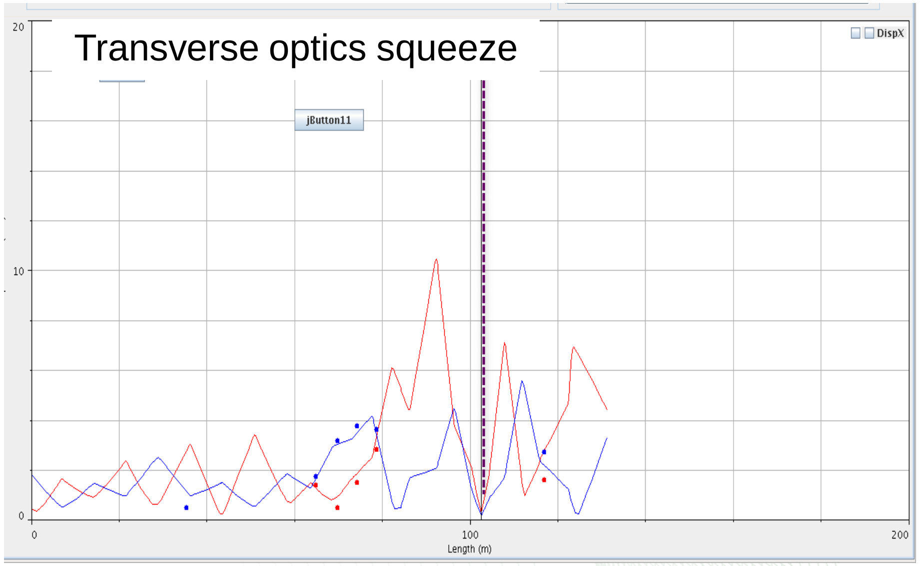


Calculated Laser Stripping Efficiency

- Achieved simultaneous demonstration optics.
- Await installation of local IP diagnostics to double check.







T. Gorlov

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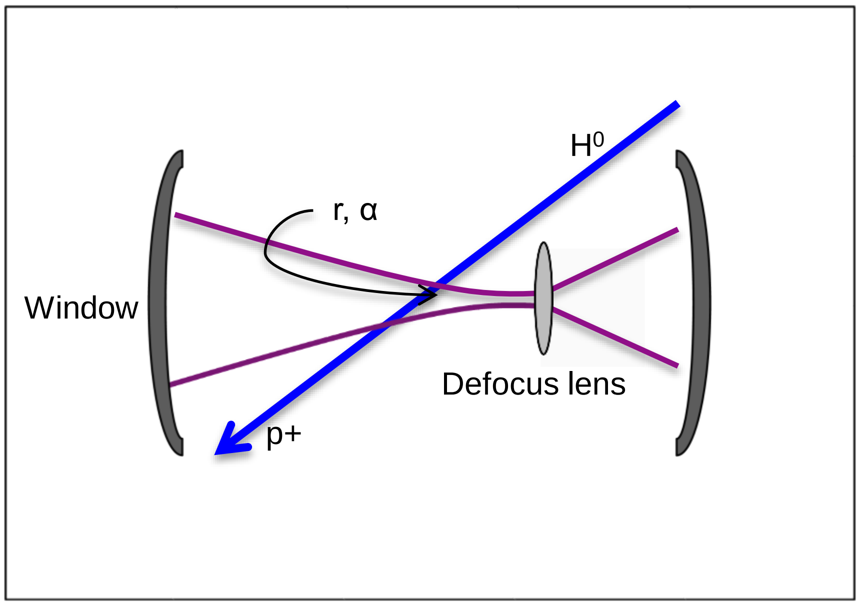
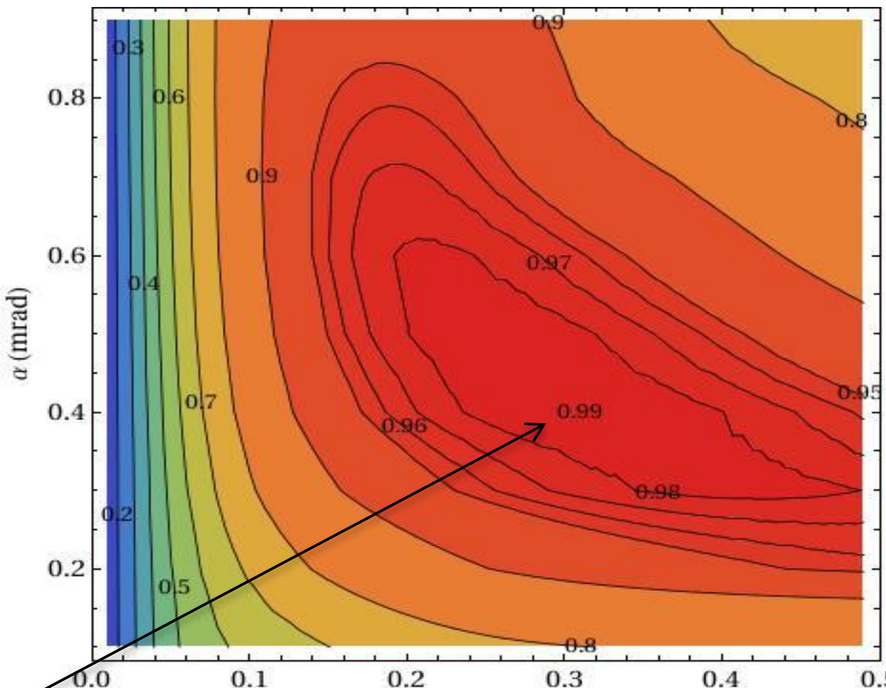
Laser Stripping Efficiency Calculation

- Using measured laser and ion beam parameters, calculate efficiency for various laser conditions.



Final Stripping Efficiency



T. Gorlov

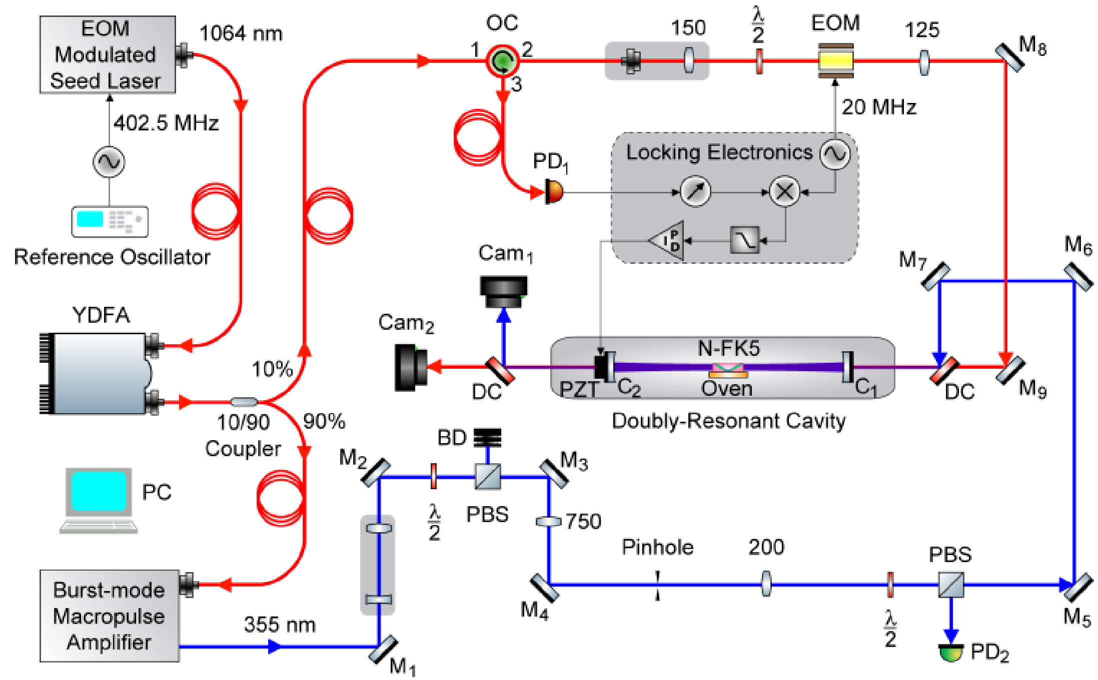
Concern about power density on defocus lens

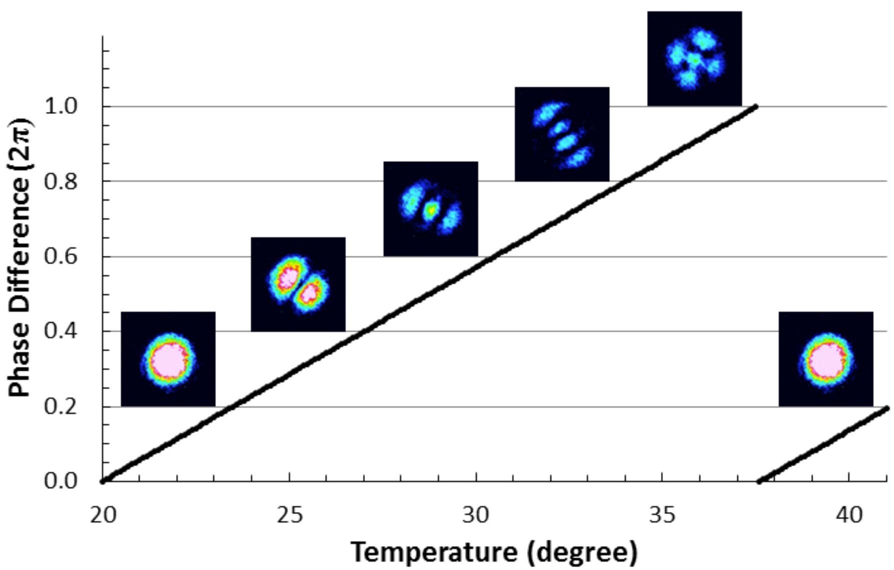
Schedule and Challenges

Task	Status
Ion Beam Preparation	
Dispersion tailoring	✓
Longitudinal and transverse squeeze	✓
Laser Beam Preparation	
Achieve UV laser power and time structure	✓
Test laser loss in transport (mock-up)	✓
Set up RSB laser table and local final optics station	Design complete
Experimental configuration	
Magnet design, fabrication, and test	✓
Experimental station design, fabrication, and test	✓
Laser transport line design, fabrication	Final drawings in progress
Installation	
Pull all cables	✓
Install experimental station	Pending; summer 2015
Install laser transport line	Pending; summer 2015, winter 2016

Laser Power Recycling Cavity Development

- Can not lock UV laser directly
- Double-resonance power recycling optical cavity is based on temperature-controlled phase tuning.





- Experimental result of phase tuning

Y. Liu, A. Rakhman, M. Baude