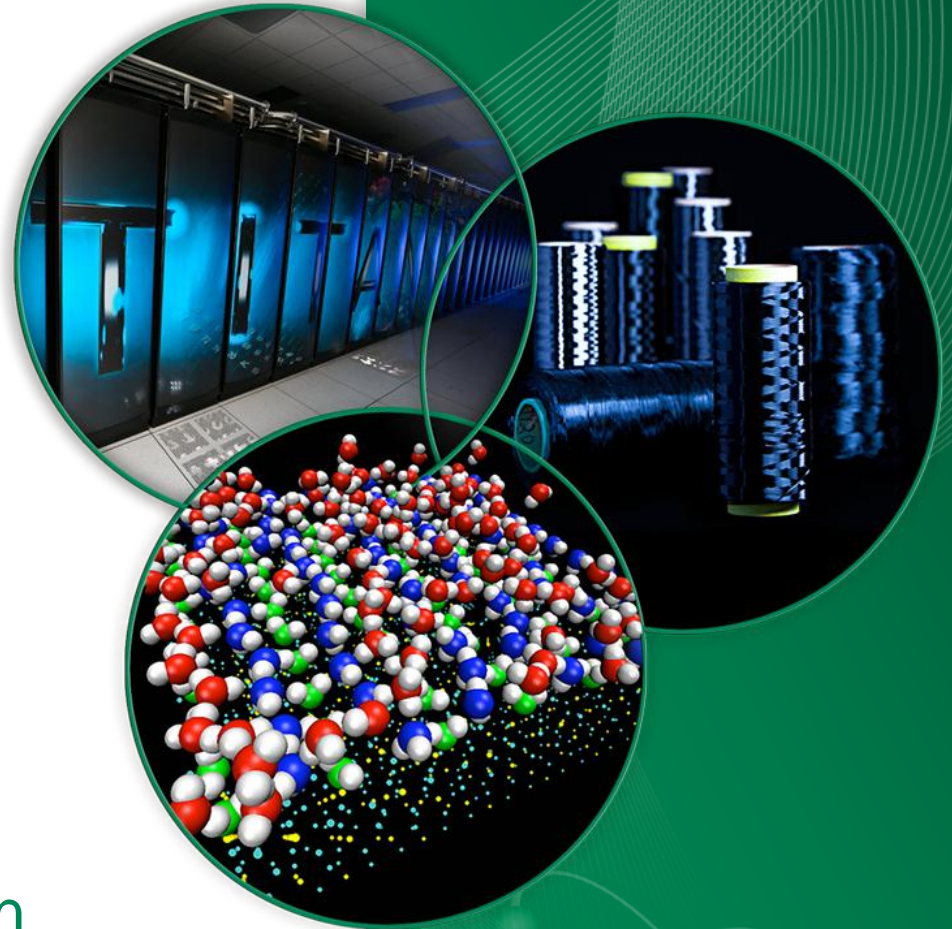


Laser Wire Based Parallel Profile Scan of H⁻ Beam at SNS

**Y. Liu, C. Long,
C. Huang, R. Dickson,
A. Aleksandrov,
C. Peters, D. Brown**

Research Accelerator Division
Spallation Neutron Source
Oak Ridge National Laboratory



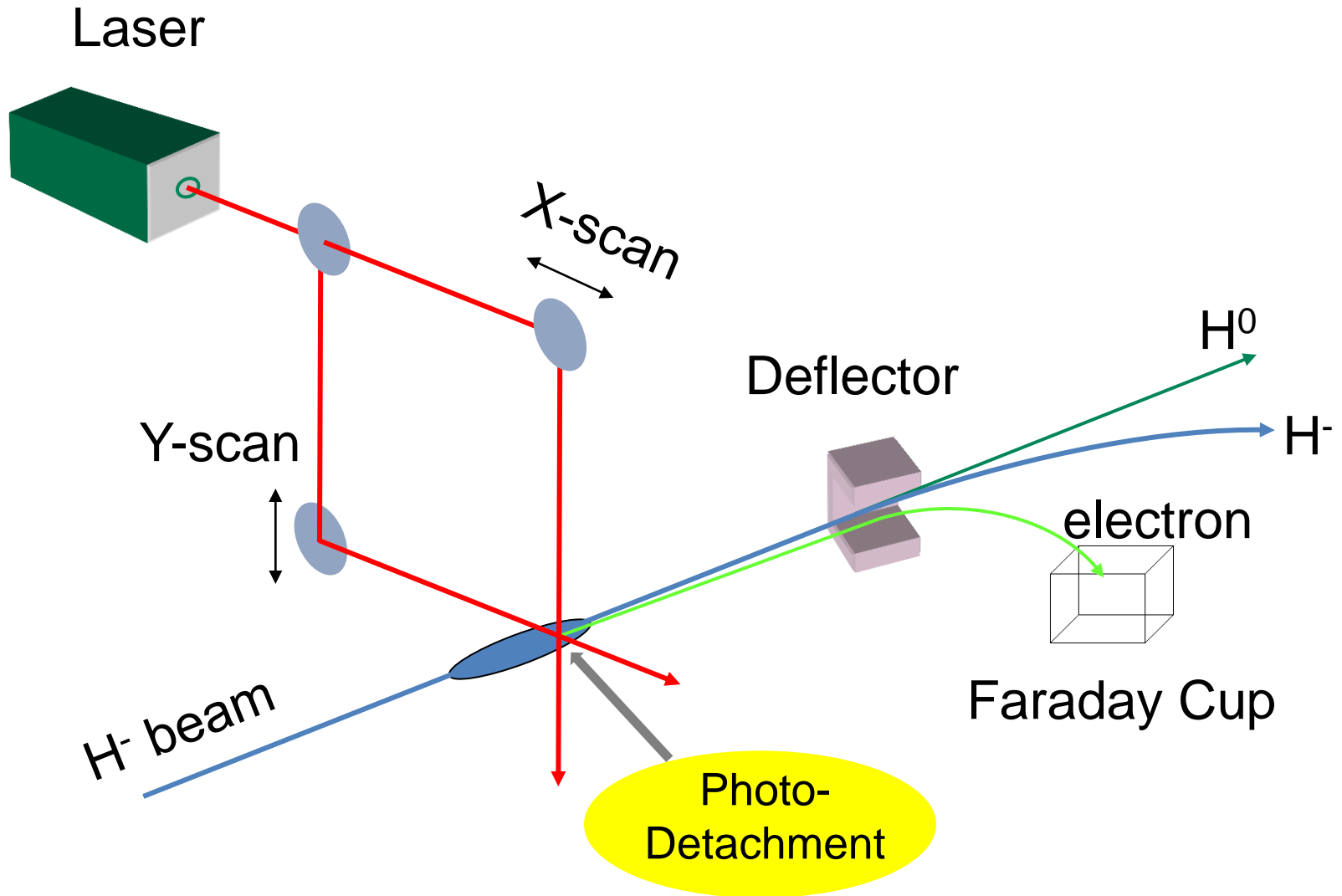
OUTLINE

- Motivation
- Principle of laser wire measurement
- System modifications for simultaneous profile scan
- 9-station simultaneous profile measurement results
- Commissioning experience on laser based diagnostics
- Conclusion

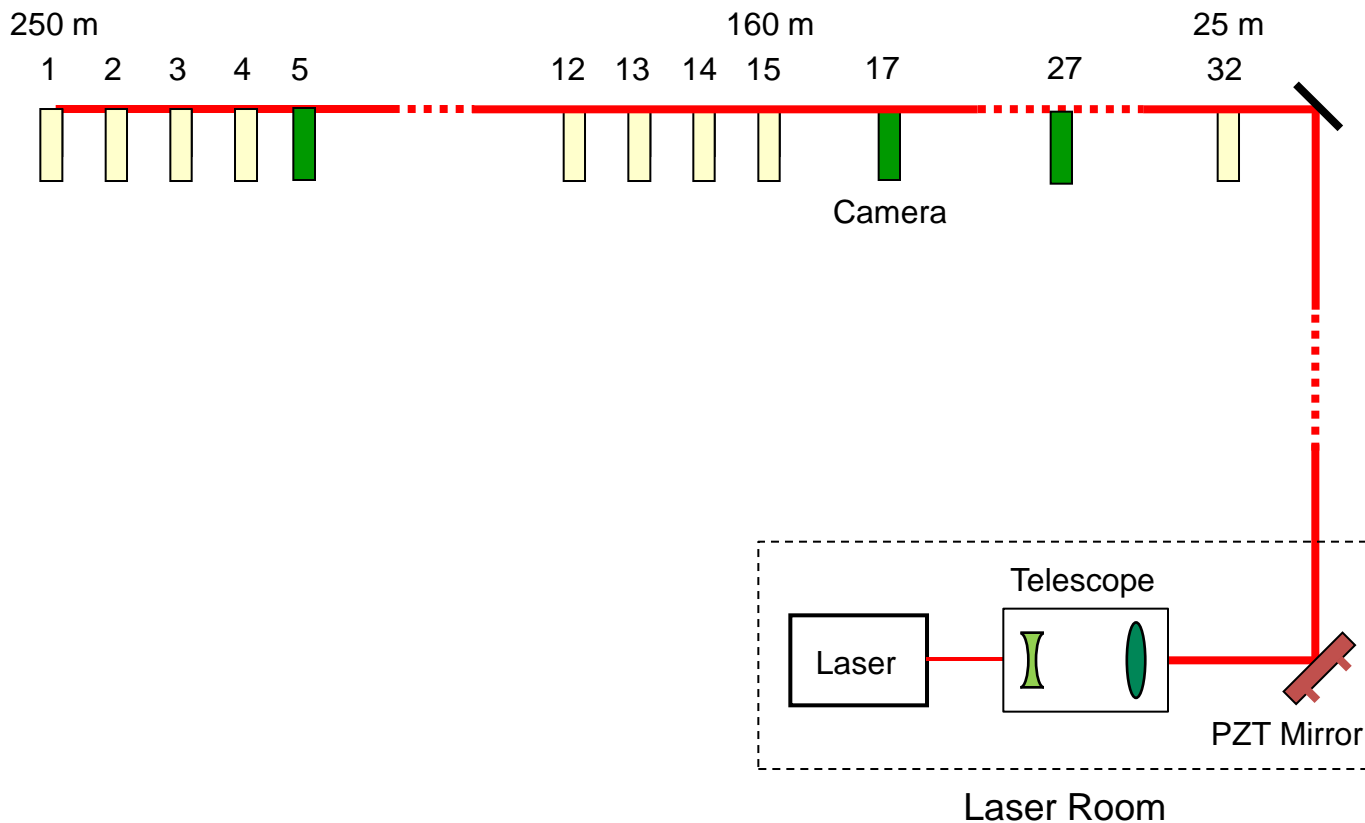
Motivation

- **Advantages of laser wire profile/emittance monitor:**
 - Measurement is non-intrusive and can be conducted on neutron production beam.
 - No moving parts in vacuum and therefore no risk to superconducting cavity.
 - Novel capability: measurement of profile/emittance of individual minipulses.
- **Previously laser wire profile measurements have only been performed serially since a single light source is used.**
- **On the other hand, physics study such as the SCL modeling at SNS requires the measurement of H- beam profiles at different locations along the acceleration path and on different accelerator settings.**
- **A simultaneous profile measurement would be especially helpful to improve the efficiency and accuracy of the physics studies.**

Principle of Laser Wire Measurement



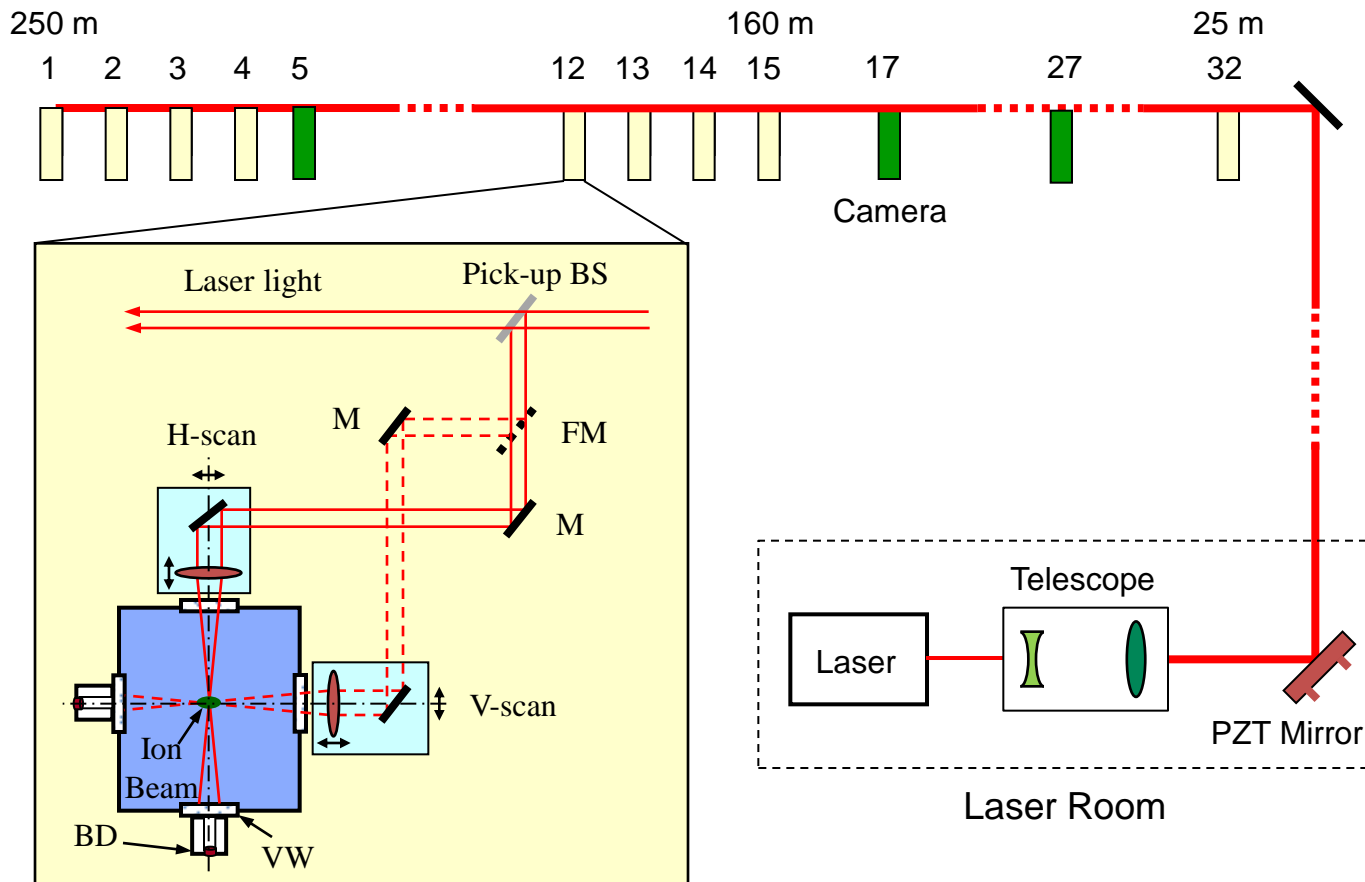
SCL Laser Wire Profile Measurement System



[Liu et al, NIMA 612 \(2010\) 241–253;](#)

[Appl. Opt. 49 \(2011\) 6816-6823.](#)

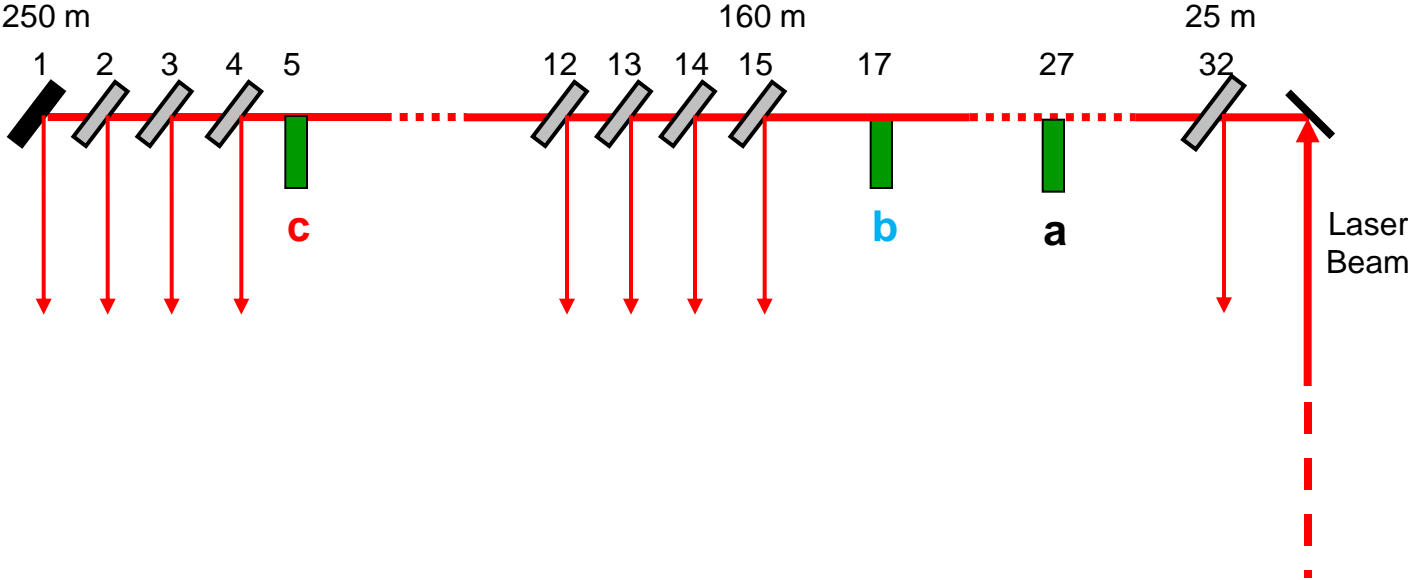
SCL Laser Wire Profile Measurement System



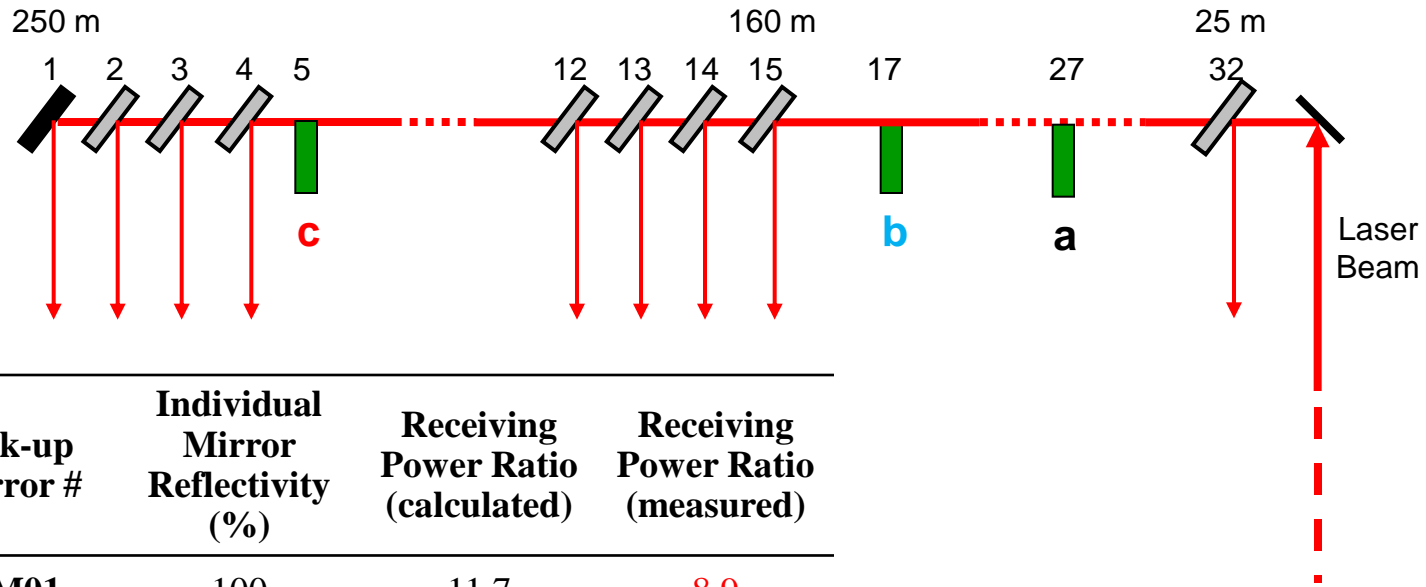
[Liu et al, NIMA 612 \(2010\) 241–253;](#)

[Appl. Opt. 49 \(2011\) 6816-6823.](#)

Laser Transport Line

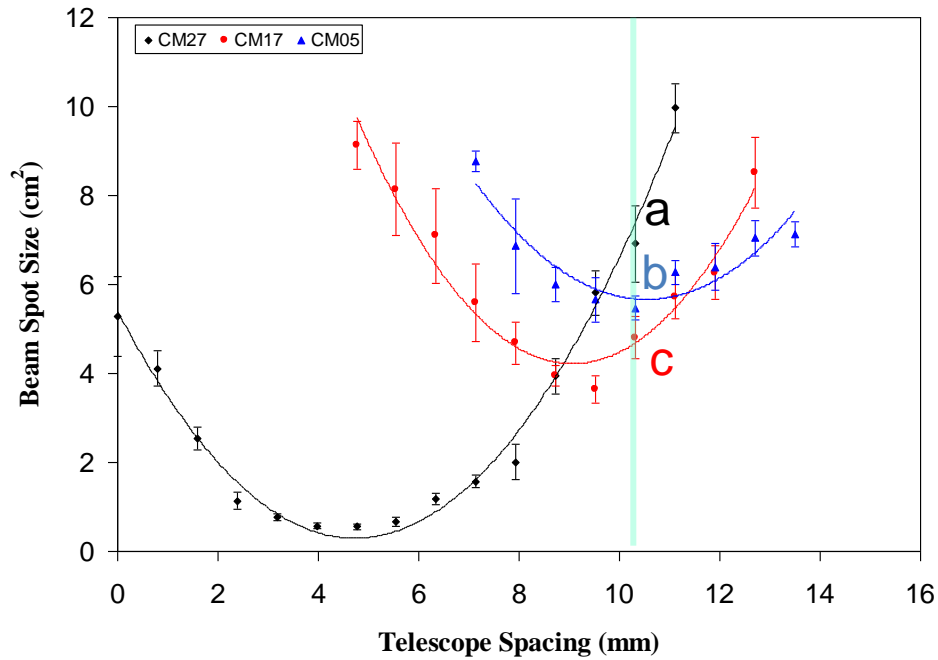
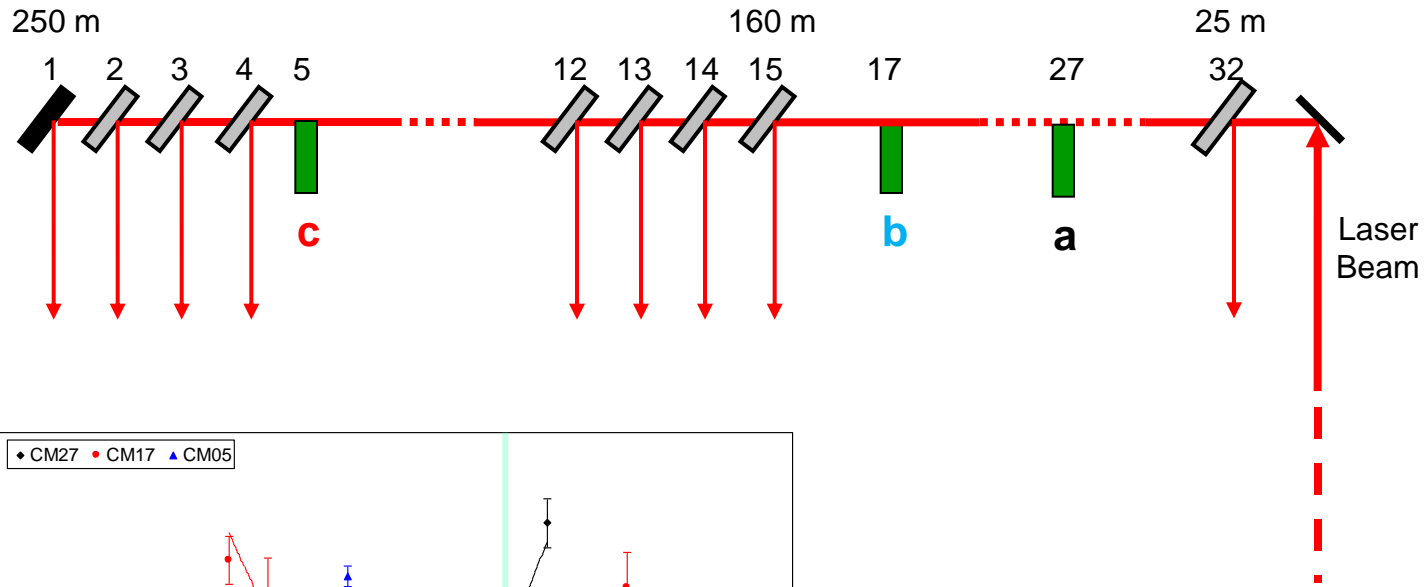


Laser Transport Line

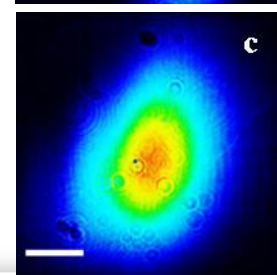
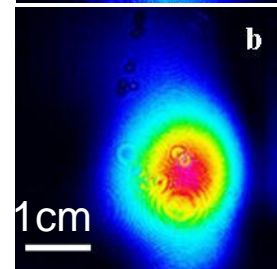
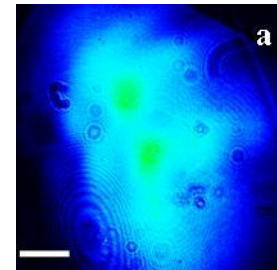
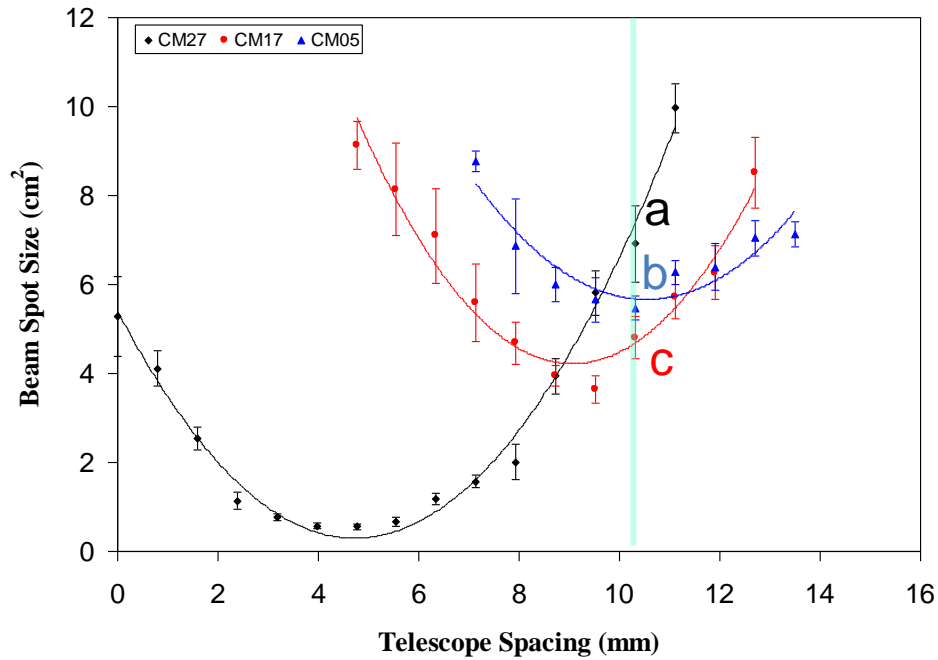
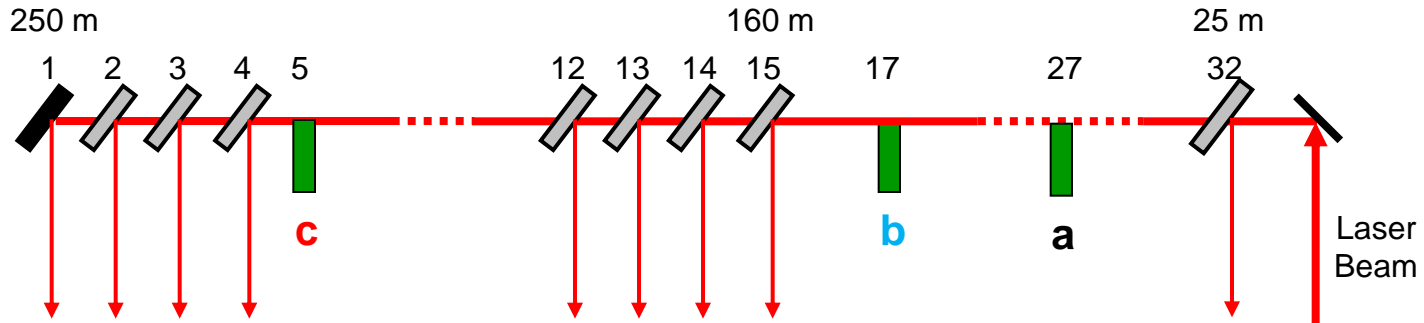


Pick-up Mirror #	Individual Mirror Reflectivity (%)	Receiving Power Ratio (calculated)	Receiving Power Ratio (measured)
CM01	100	11.7	8.9
CM02	50	11.7	11.4
CM03	33	11.7	9.3
CM04	25	11.7	11.6
CM12	20	11.7	12.7
CM13	20	14.6	13.8
CM14	10	8.1	10.2
CM15	10	9.0	8.7
CM32	10	10.0	8.2

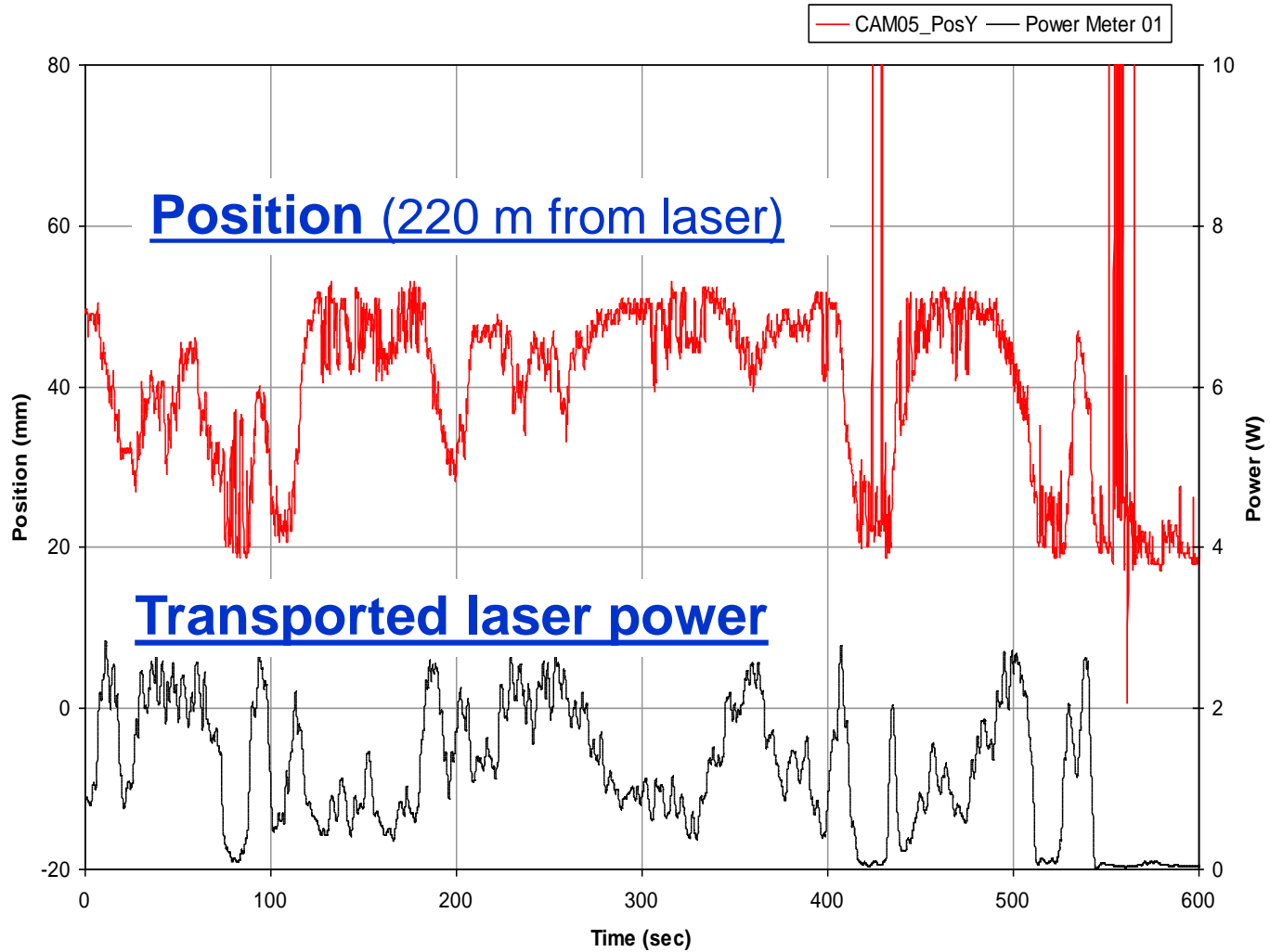
Laser Transport Line



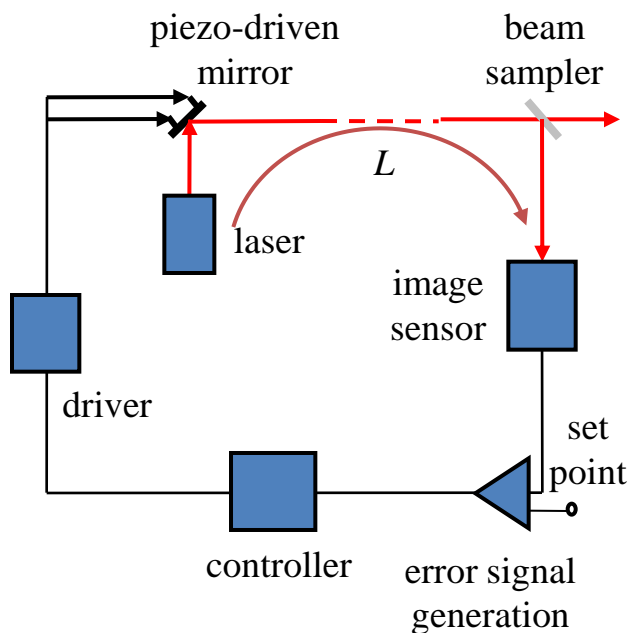
Laser Transport Line



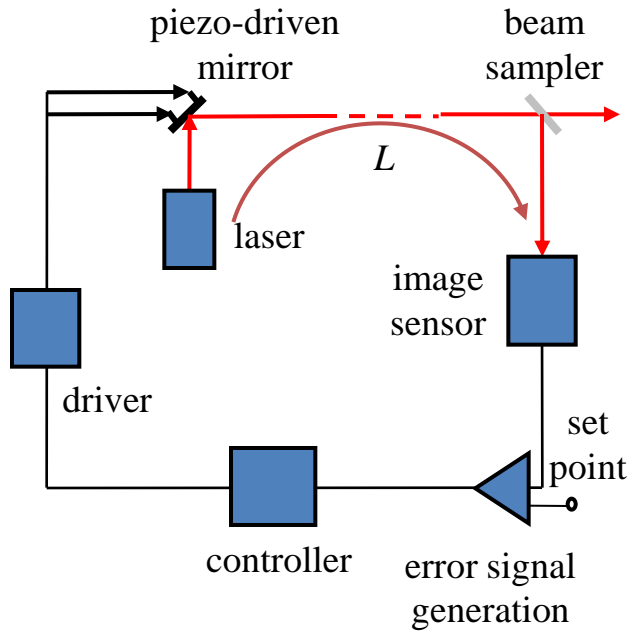
Laser Beam Pointing Stabilization



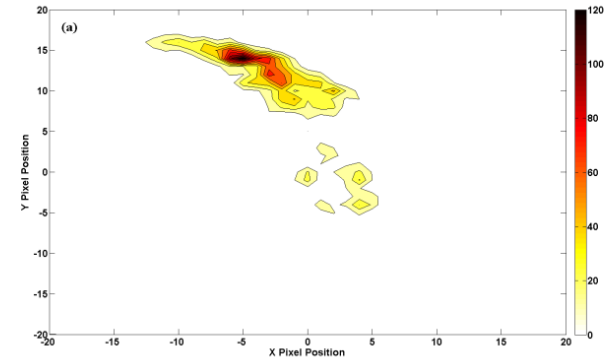
Laser Beam Pointing Stabilization



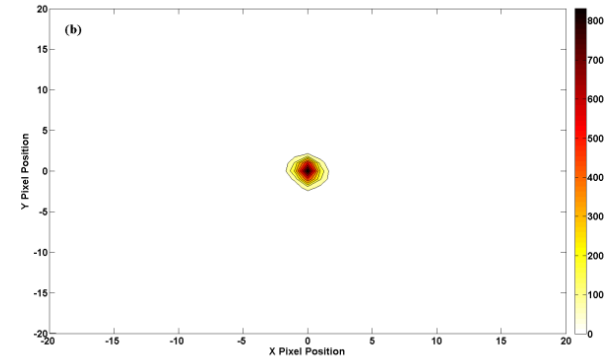
Laser Beam Pointing Stabilization



Feedback off



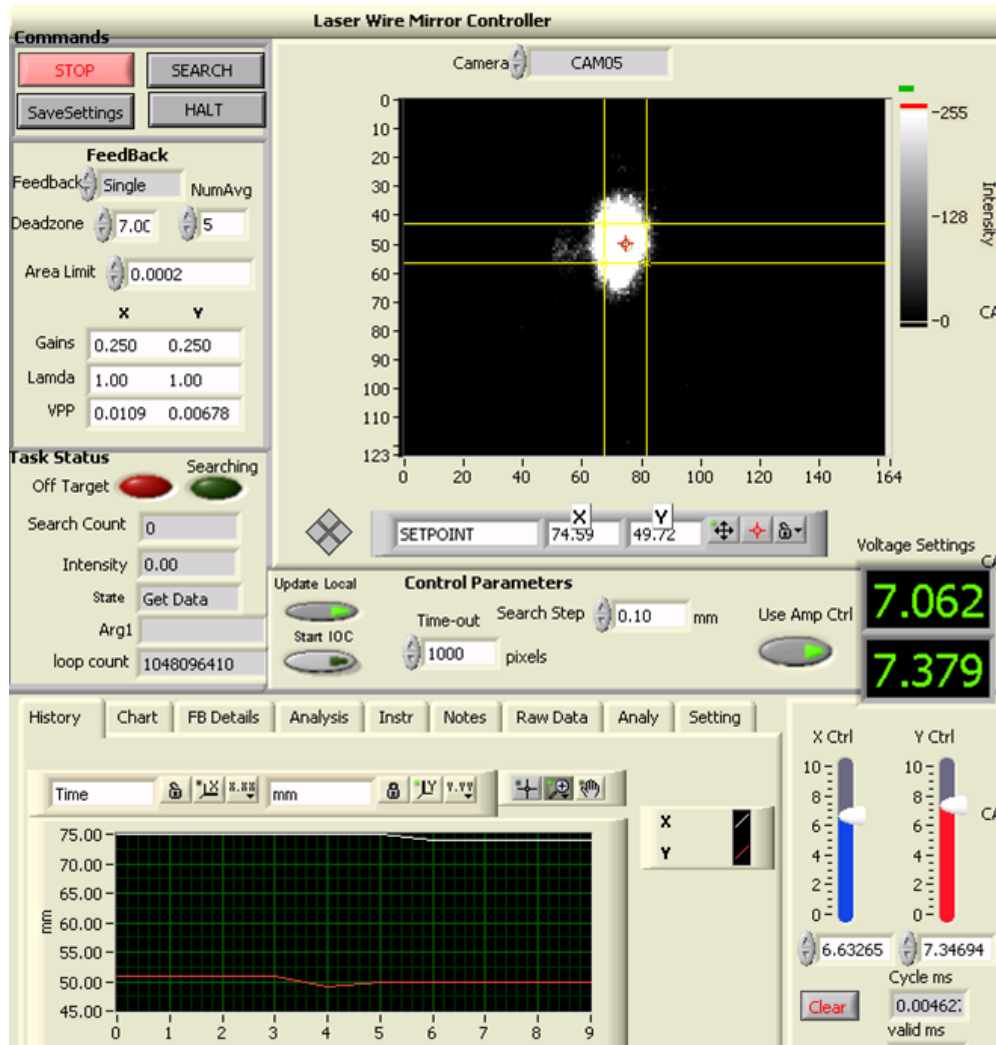
Feedback on



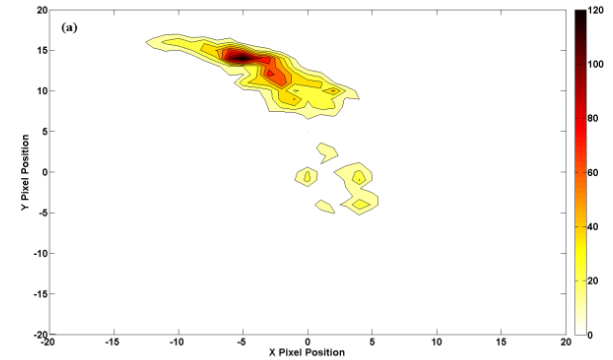
$\pm 1.25 \text{ mm @ } 250 \text{ m}$

Hardin et al, *Opt. Express* **19** (2011) 2874-2885.

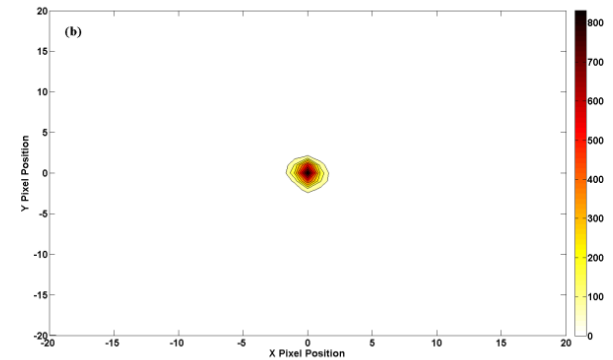
Laser Beam Pointing Stabilization



Feedback off



Feedback on

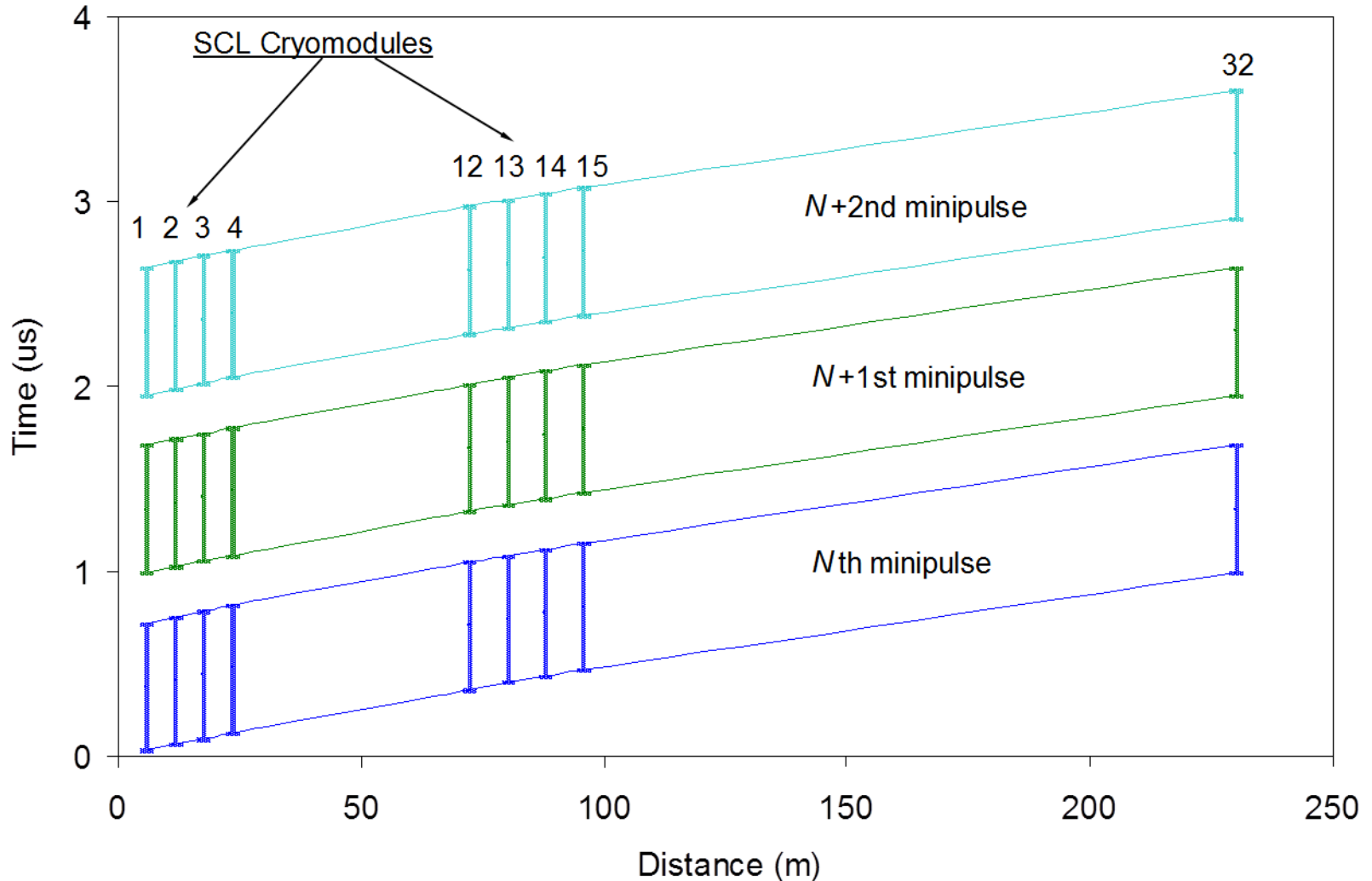


$\pm 1.25 \text{ mm @ } 250 \text{ m}$

Hardin et al, *Opt. Express* **19** (2011) 2874-2885.

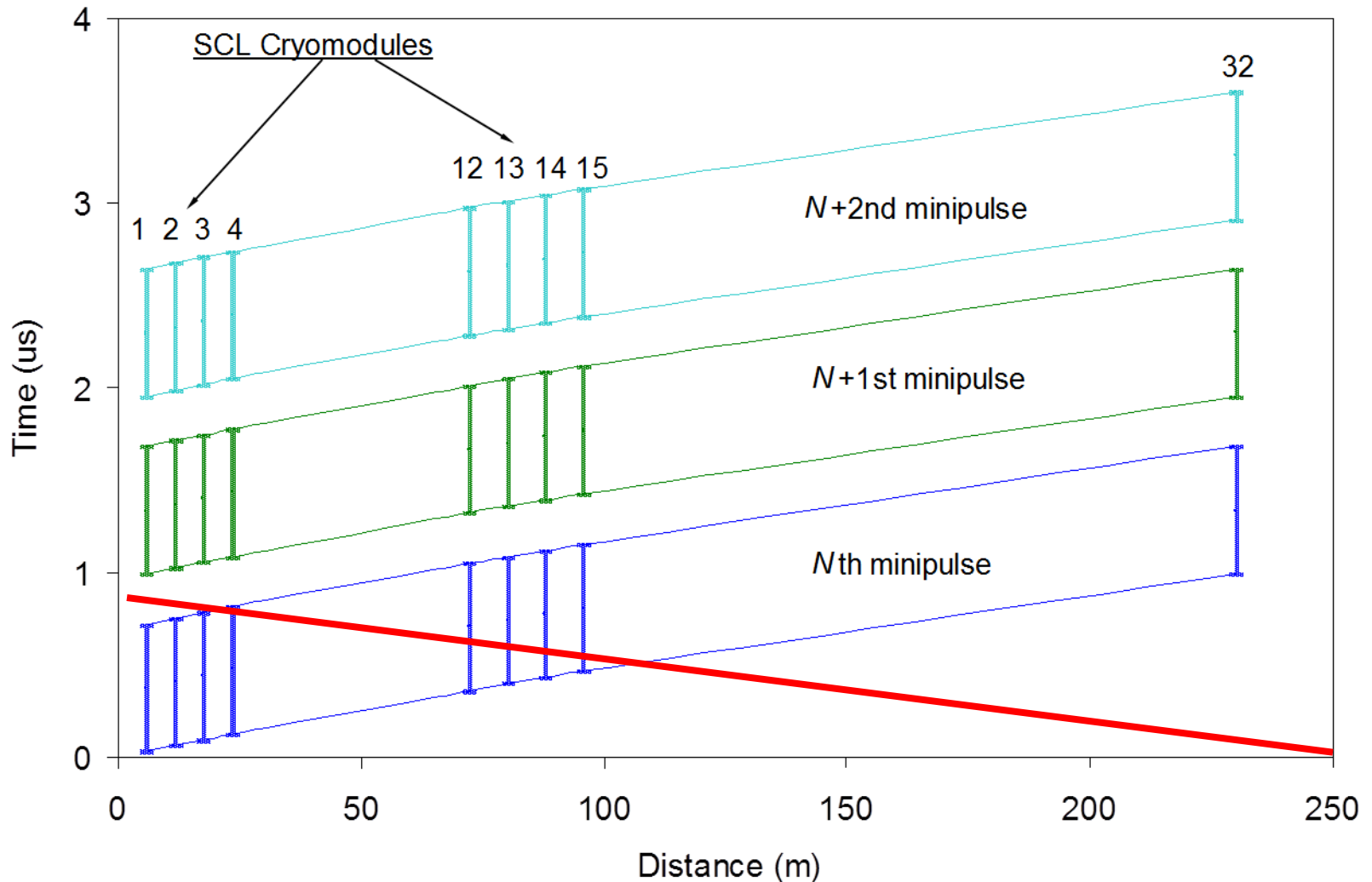
Phase Tuning between Laser and H- Pulses

Propagation of Ion Beam and Light Beam



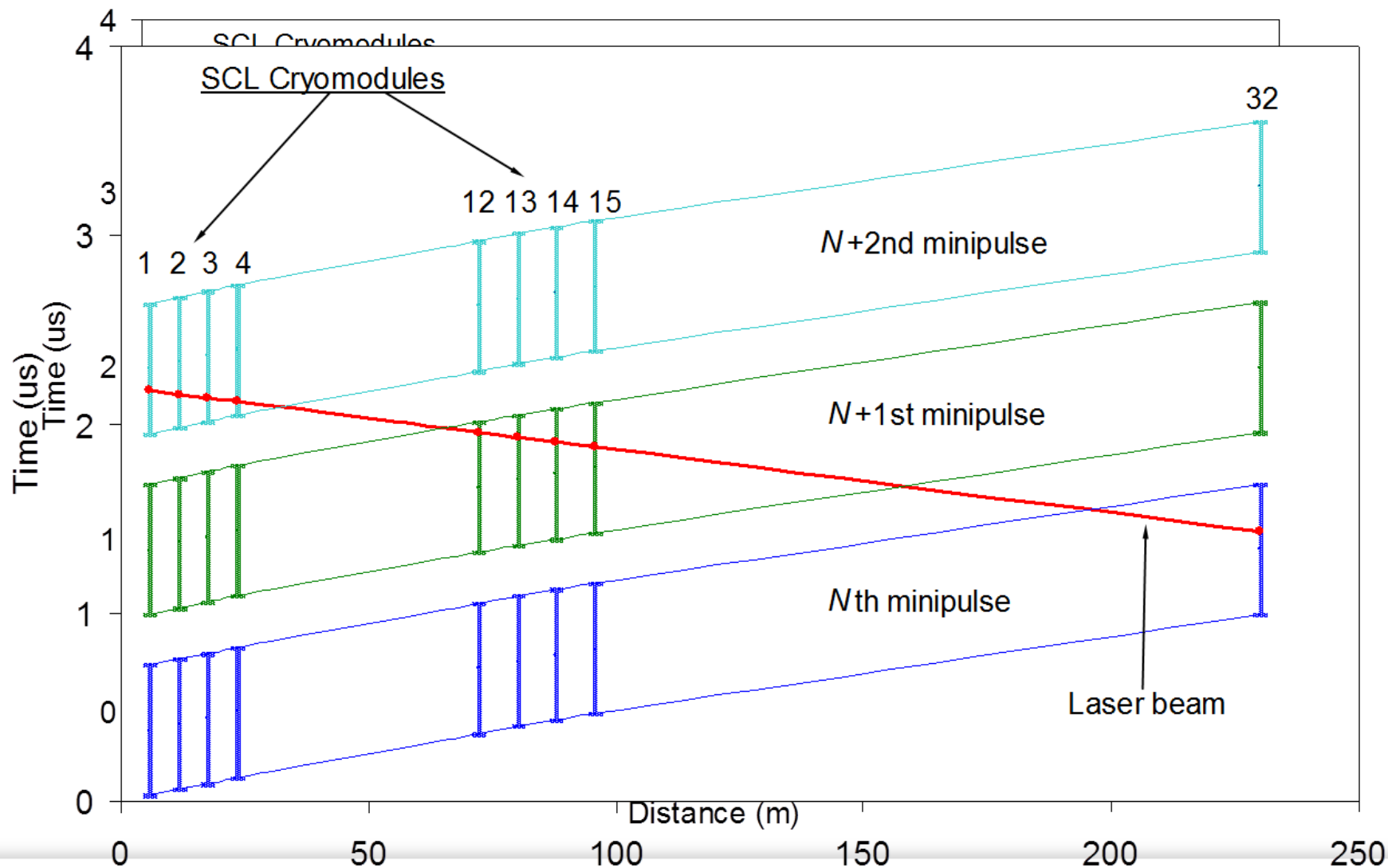
Phase Tuning between Laser and H- Pulses

Propagation of Ion Beam and Light Beam



Phase Tuning between Laser and H- Pulses

Propagation of Ion Beam and Light Beam



EDM Screens for Laser Wire System

Laser Wire Transfer Line

<i>Label</i>	<i>Description</i>	<i>Retract</i>	<i>mm</i>	<i>Insert</i>	<i>Command</i>		
LW_01	Station 01	<input checked="" type="radio"/>	-0.037	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_02	Station 02	<input checked="" type="radio"/>	0.042	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_03	Station 03	<input checked="" type="radio"/>	-0.058	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_04	Station 04	<input checked="" type="radio"/>	0.138	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_12	Station 12	<input checked="" type="radio"/>	-0.016	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_13	Station 13	<input checked="" type="radio"/>	0.069	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_14	Station 14	<input checked="" type="radio"/>	-0.021	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_15	Station 15	<input checked="" type="radio"/>	-0.016	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_32	Station 32	<input checked="" type="radio"/>	0.021	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim
LW_EMIT	Beam Block	<input checked="" type="radio"/>	0.000	<input type="radio"/>	Rtn Lim	Set Pt	Ins Lim

From EPICS, user can select one, multiple, or all scanners

EDM Screens for Laser Wire System



From EPICS, user can select scan range, step size, average number. Fitting is automatically conducted.

Simultaneous Profile Scan

Smoke Alarms

RFQ Mod1	DTL Mod3	DTL Mod5	CCL Mod1	CCL Mod2	CCL Mod3	CCL Mod4
CO2 DISCHARGE	CO2 DISCHARGE	CO2 DISCHARGE	CO2 DISCHARGE	CO2 DISCHARGE	CO2 DISCHARGE	CO2 DISCHARGE

Note: The CO2 discharge button remains below the associated modulator. When the smoke detector indication is present, discharge requires confirmation.

Current Rep-Rate to Target: 50.9 @ 854.03 KW

Ext. Air Temp. 74.8 F

Beam Halo One Minute Avg Temps on Target: 147.3 F, 199.8 F, 154.8 F, 197.1 F

65 KV OK, RFQ OK

SCL_Diag:LW 01

Pos-mm	Pos-fb
40.001	39.396
Ampl	0.253
Mean	22.435
Sigma	2.375
Offset	0.008
Fit Area	3.016
Raw Area	2.967

Pos-mm	Pos-fb
40.001	39.805
Ampl	0.281
Mean	27.611
Sigma	1.889
Offset	0.008
Fit Area	2.664
Raw Area	2.712

Simultaneous Profile Scan

	LW01		LW02		LW03		LW04		LW12		LW13		LW14		LW15		LW32	
Minipulse #	101		101		101		101		100		100		100		100		99	
Samples/Point	75	15	15	15	15	15	15	15	75	15	15	15	15	15	15	15	75	15
Start mm	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Stop mm	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
Delta mm	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Horizontal Mean	22.435		11.644		23.366		29.330		28.293		21.944		30.443		22.360		25.035	
Vertical Mean	27.611		25.383		32.769		22.052		28.497		27.230		23.918		22.035		19.340	

Horiz Vert

Set All Stations

Minipulse #

Samples/Point

Start mm

Stop mm

Delta mm

Horizontal

01 Fit On

01 Raw On

02 Fit On

02 Raw On

03 Fit On

03 Raw On

04 Fit On

04 Raw On

12 Fit On

12 Raw On

13 Fit On

13 Raw On

14 Fit On

14 Raw On

15 Fit On

15 Raw On

32 Fit On

32 Raw On

Scan State

LW01 Done

Horiz

LW02 Done

Horiz

LW03 Done

Horiz

LW04 Done

Horiz

LW12 Done

Horiz

LW13 Done

Horiz

LW14 Done

Horiz

LW15 Done

Horiz

LW32 Done

Horiz

Vertical

01 Fit On

01 Raw On

02 Fit On

02 Raw On

03 Fit On

03 Raw On

04 Fit On

04 Raw On

12 Fit On

12 Raw On

13 Fit On

13 Raw On

14 Fit On

14 Raw On

15 Fit On

15 Raw On

32 Fit On

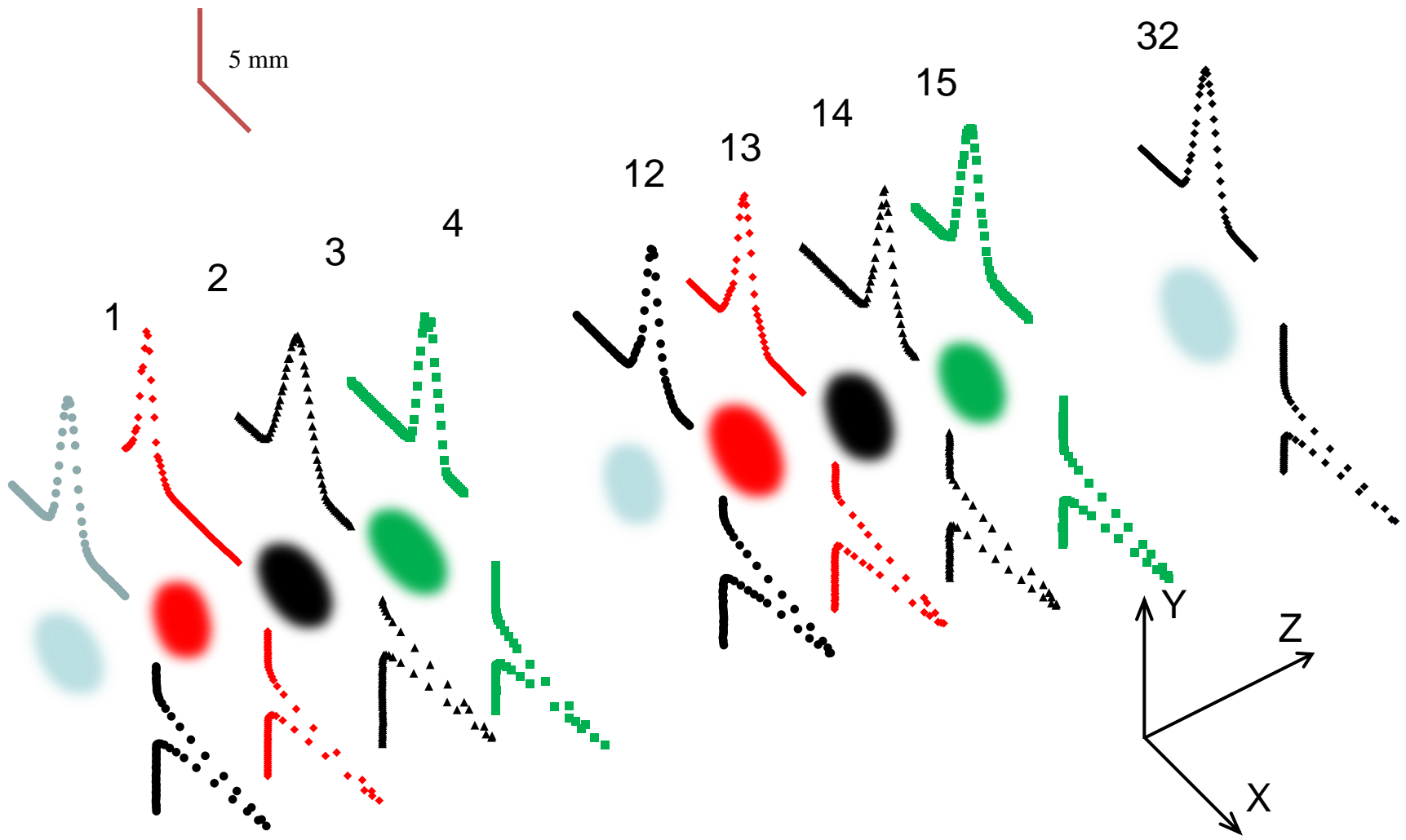
32 Raw On

Estimated Beam Parameters (April 15, 2013)

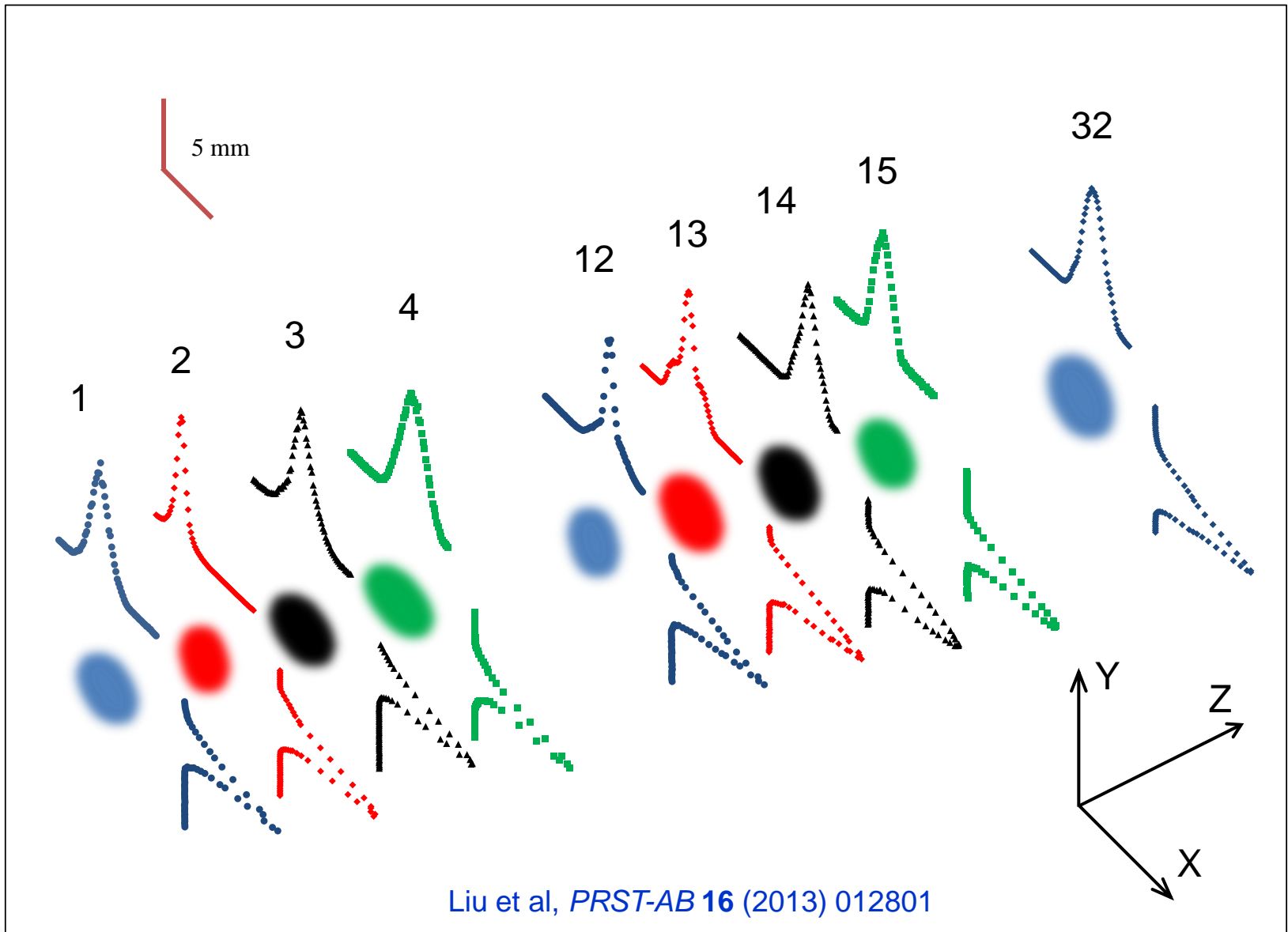
Location	Amplitude (mV)	Beam Center (mm)	Beam Size (mm)	Offset (mV)	R ²
1H	257±3	22.460±0.019	2.317±0.024	7.3±0.2	0.999
1V	274±3	27.62±0.016	1.966±0.018	7.6±0.02	0.999
2H	171±5	11.632±0.027	2.445±0.032	5.0±0.1	0.95
2V	404±5	25.316±0.010	1.717±0.014	5.8±0.1	0.996
3H	180±2	23.152±0.031	3.790±0.032	7.9±0.3	0.997
3V	316±4	32.776±0.017	1.991±0.023	8.7±0.2	0.997
4H	213±4	28.920±0.026	2.298±0.034	7.4±0.2	0.983
4V	205±5	22.020±0.025	1.852±0.029	8.4±0.2	0.988
12H	224±2	28.232±0.017	2.226±0.018	8.6±0.2	0.989
12V	158±2	28.412±0.022	2.4118±0.022	8.0±0.2	0.997
13H	234±2	21.844±0.018	2.576±0.020	9.5±0.2	0.984
13V	226±2	27.180±0.019	2.440±0.021	8.4±0.2	0.998
14H	136±2	30.396±0.028	2.470±0.030	7.3±0.2	0.997
14V	139±2	23.808±0.024	2.322±0.027	7.0±0.2	0.995
15H	108±1	22.060±0.034	2.734±0.033	8.2±0.2	0.998
15V	137±2	22.156±0.027	2.269±0.027	8.5±0.2	0.999
32H	135±1	25.020±0.013	2.796±0.016	3.6±0.1	0.998
32V	215±2	19.304±0.009	1.802±0.012	2.9±0.1	0.995

3-D Visualization of Measured Profiles

(April 15, 2013)

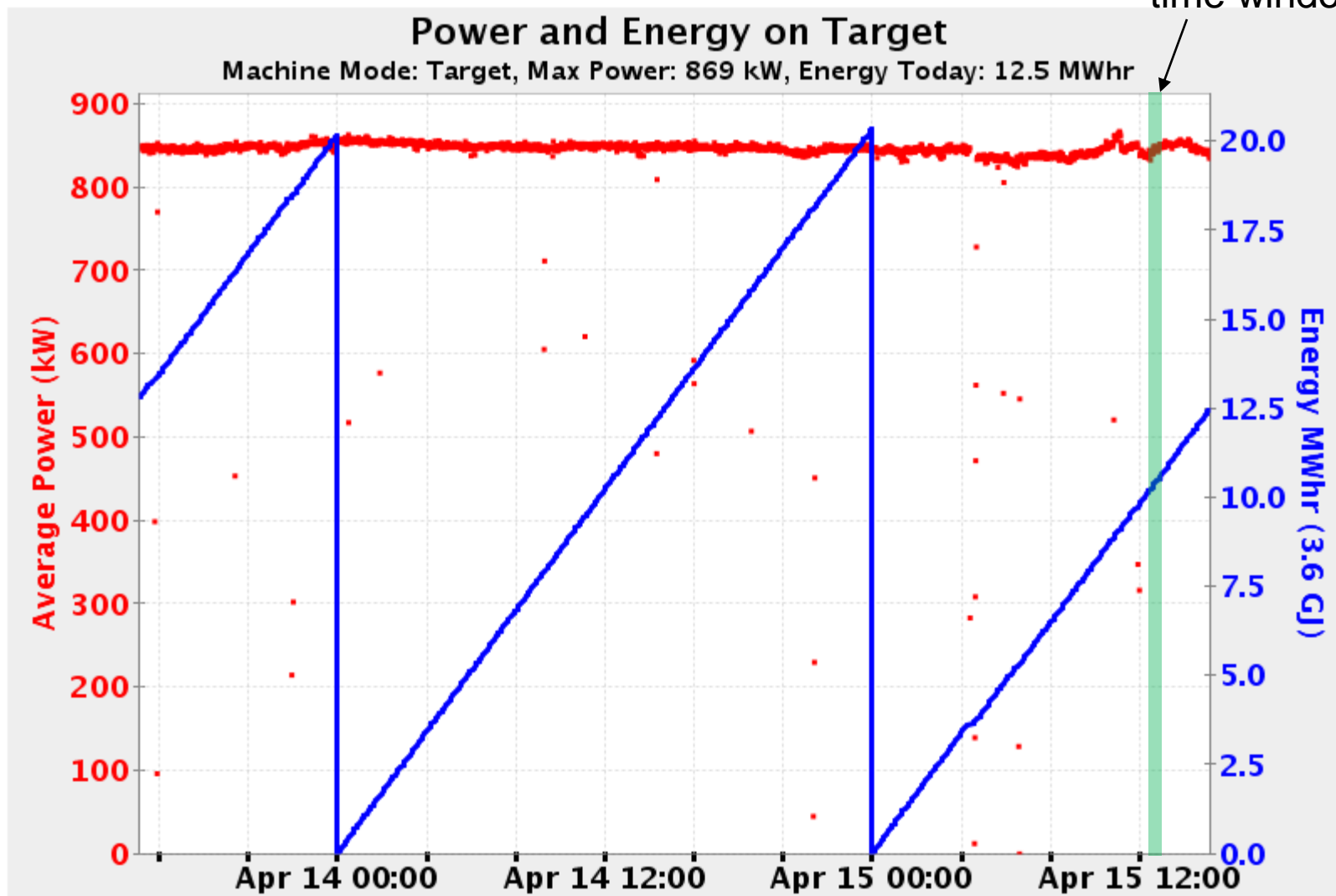


Profiles on September 13, 2012



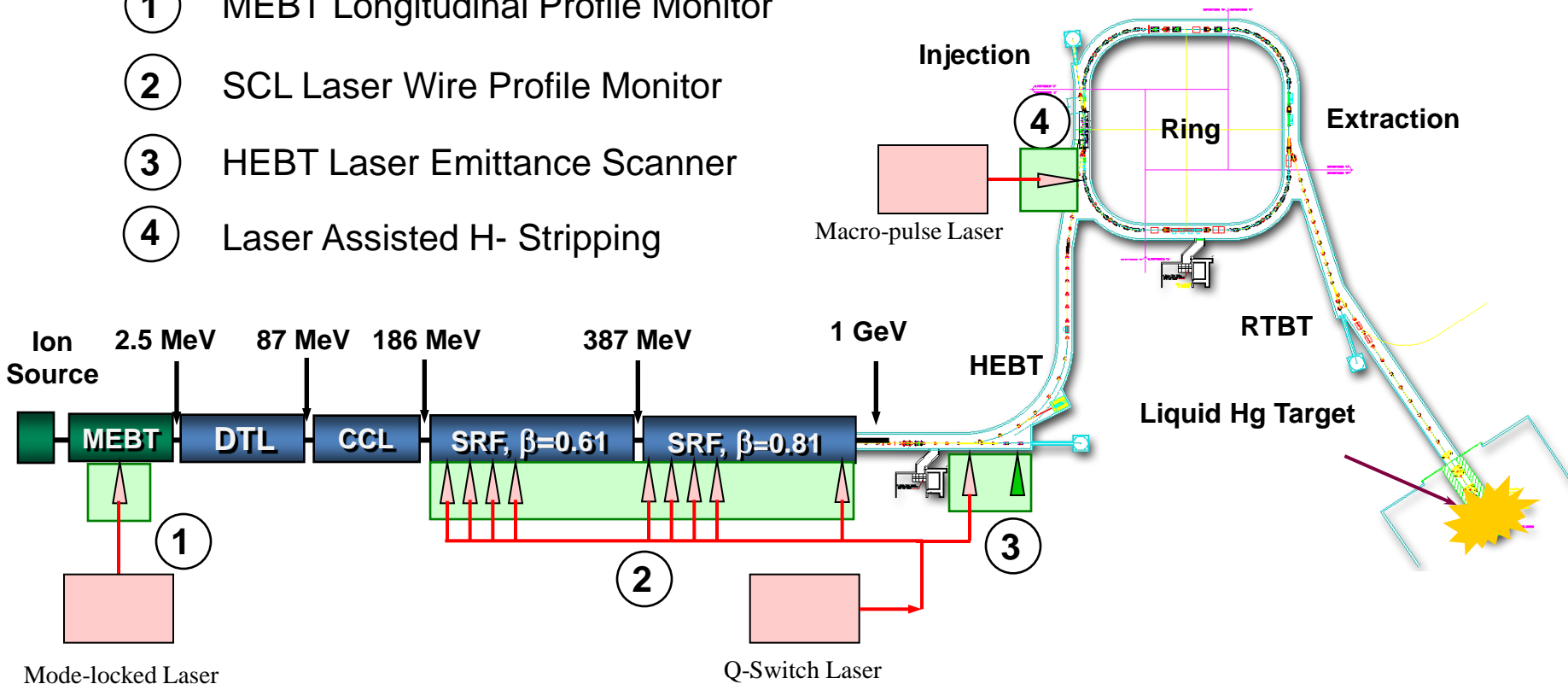
Beam Status during LW Measurement

Measurement
time window

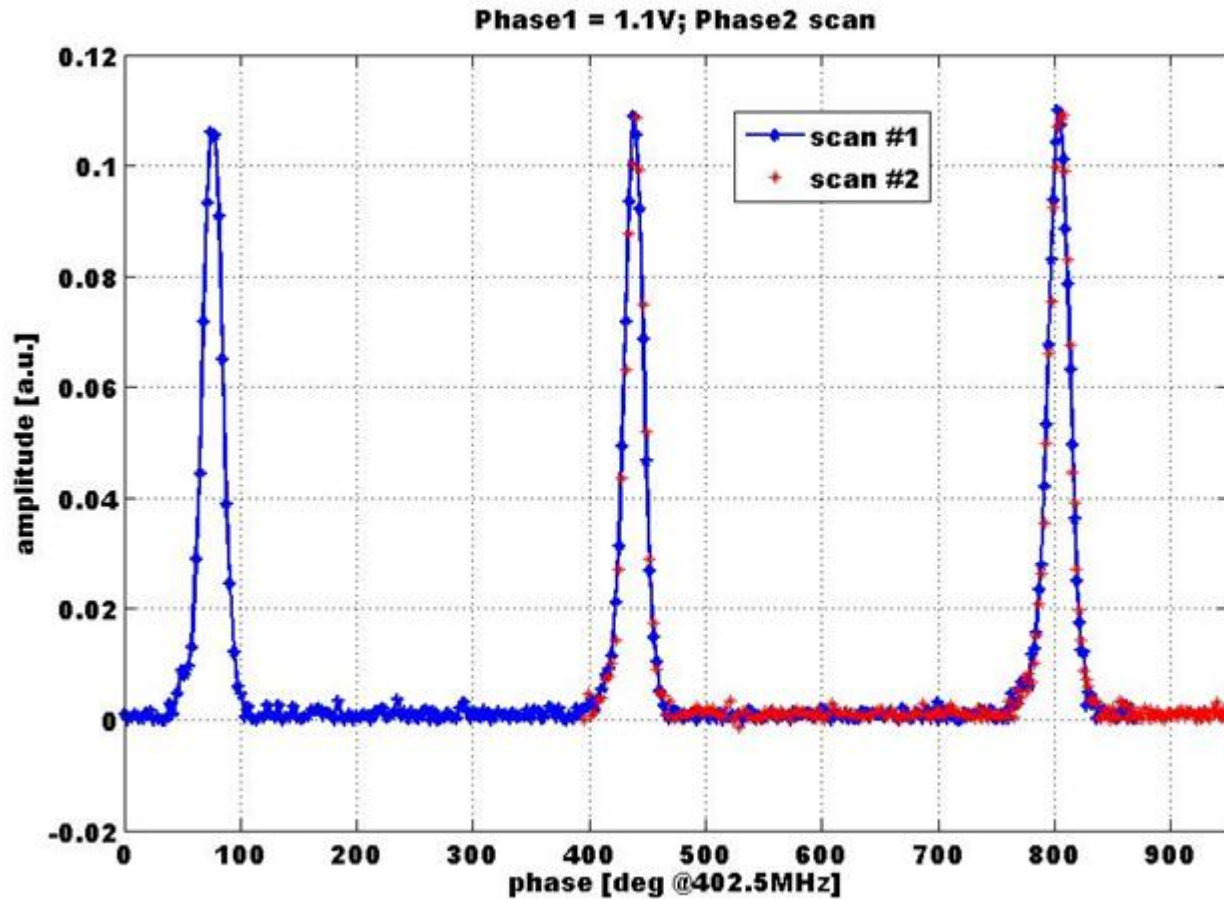


Laser Based H- Beam Diagnostics at the SNS Accelerator Complex

- ① MEBT Longitudinal Profile Monitor
- ② SCL Laser Wire Profile Monitor
- ③ HEBT Laser Emittance Scanner
- ④ Laser Assisted H- Stripping

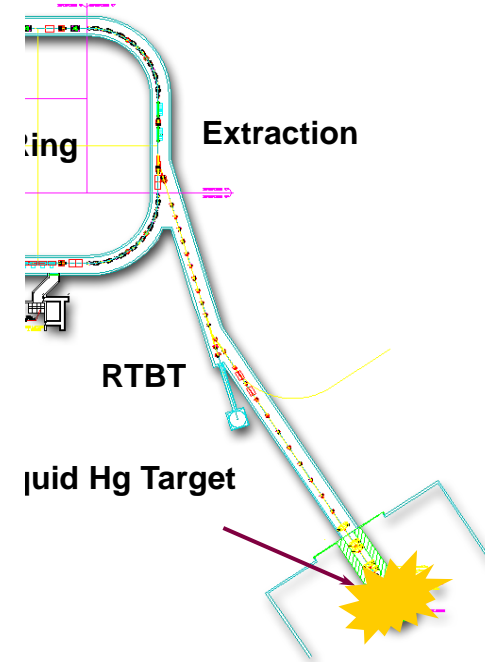


Laser Based H- Beam Diagnostics at the SNS Accelerator Complex



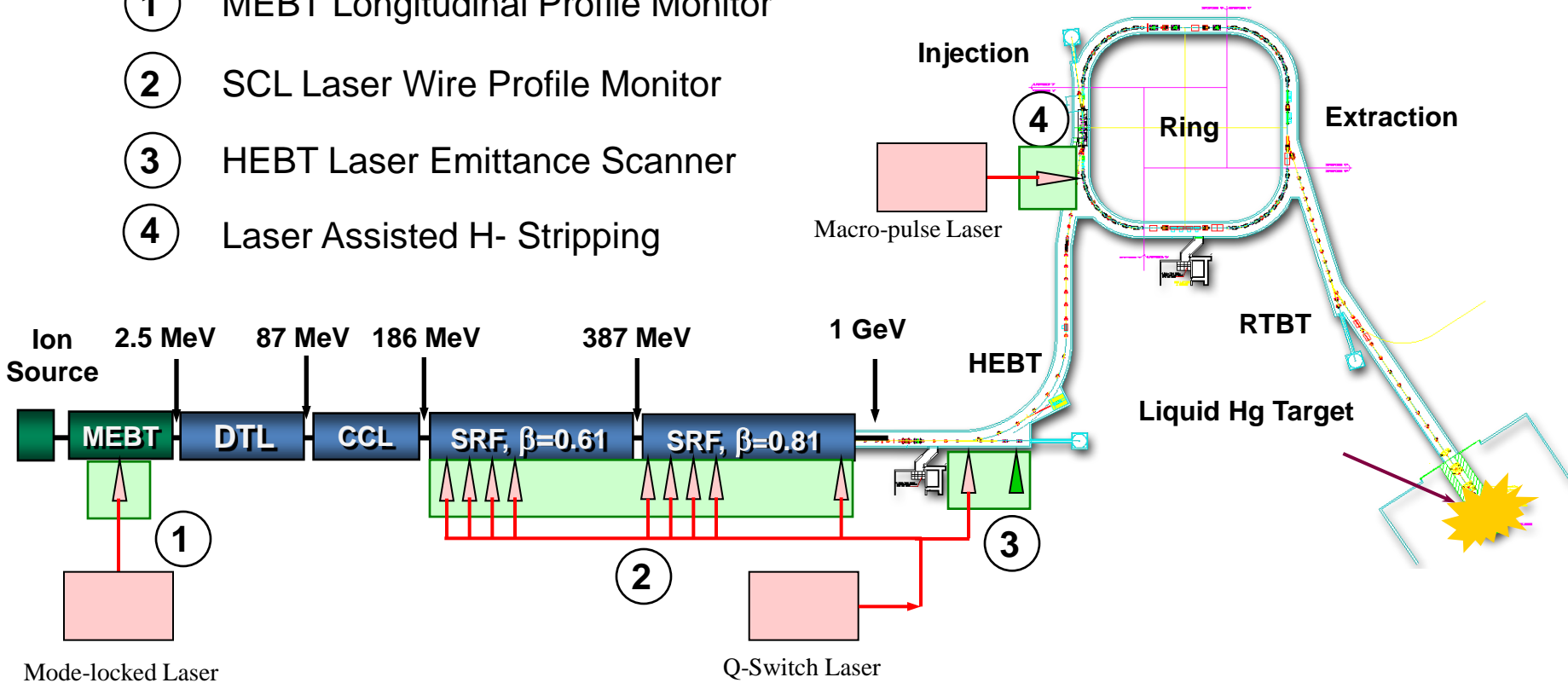
Mode-locked Laser

Q-Switch Laser

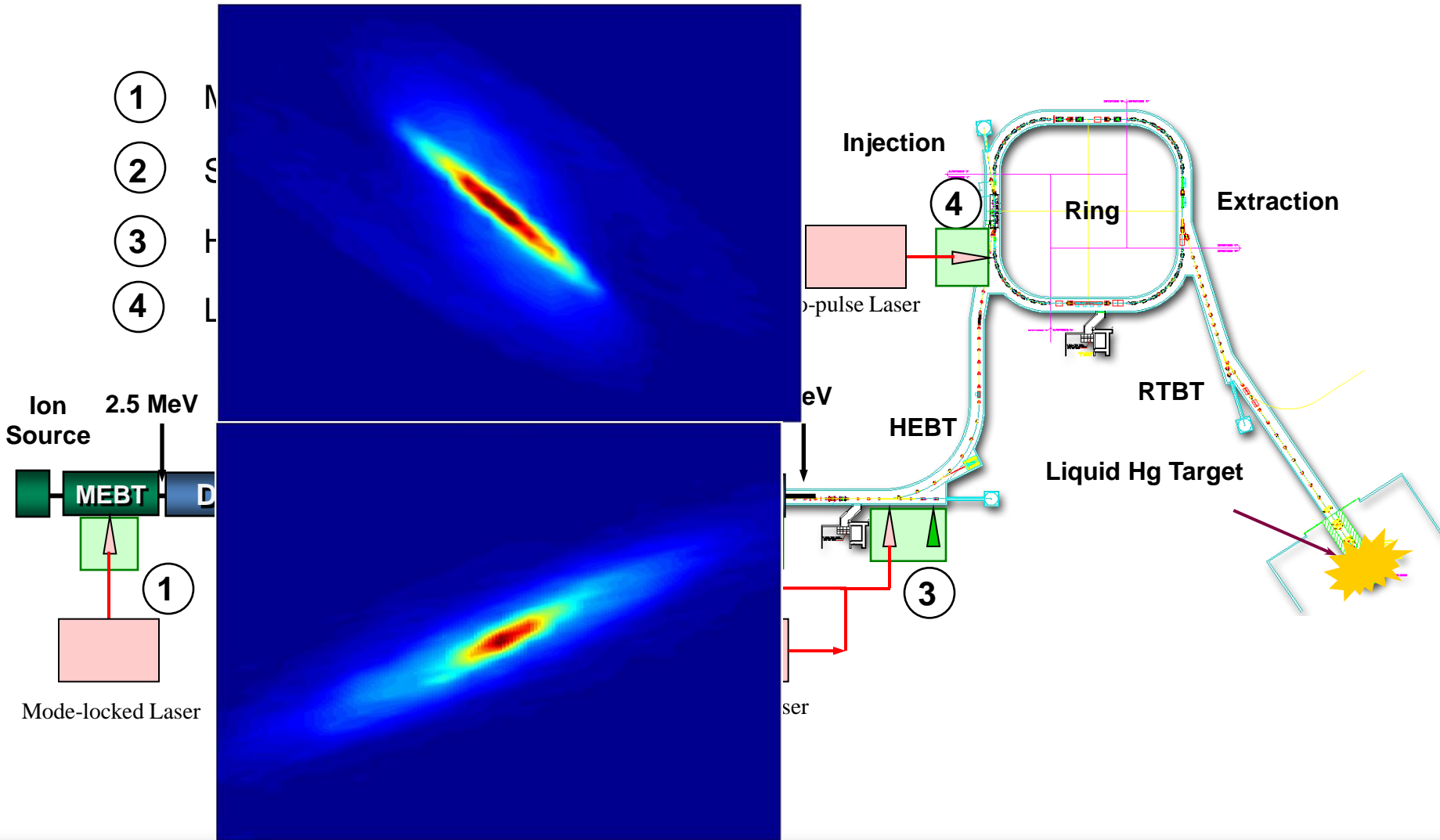


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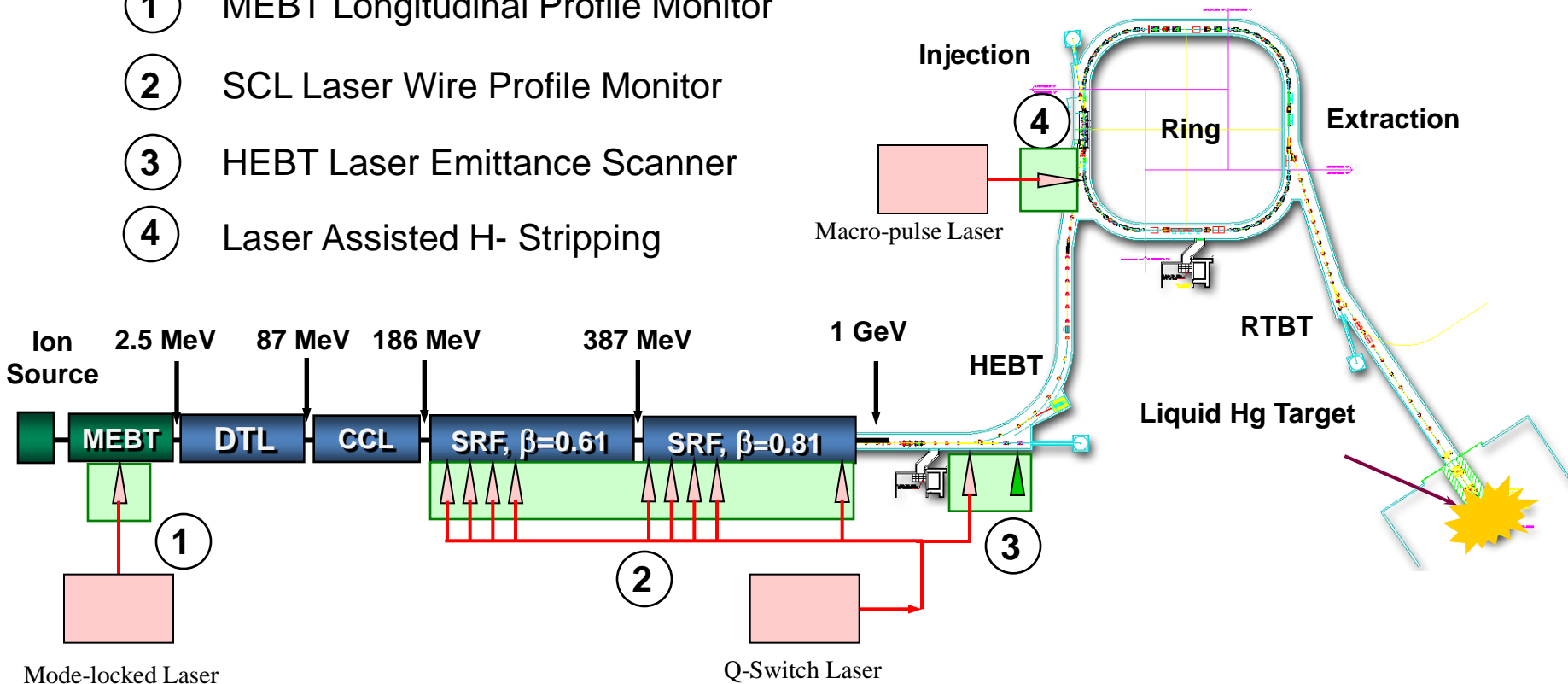


Laser Based H- Beam Diagnostics at the SNS Accelerator Complex



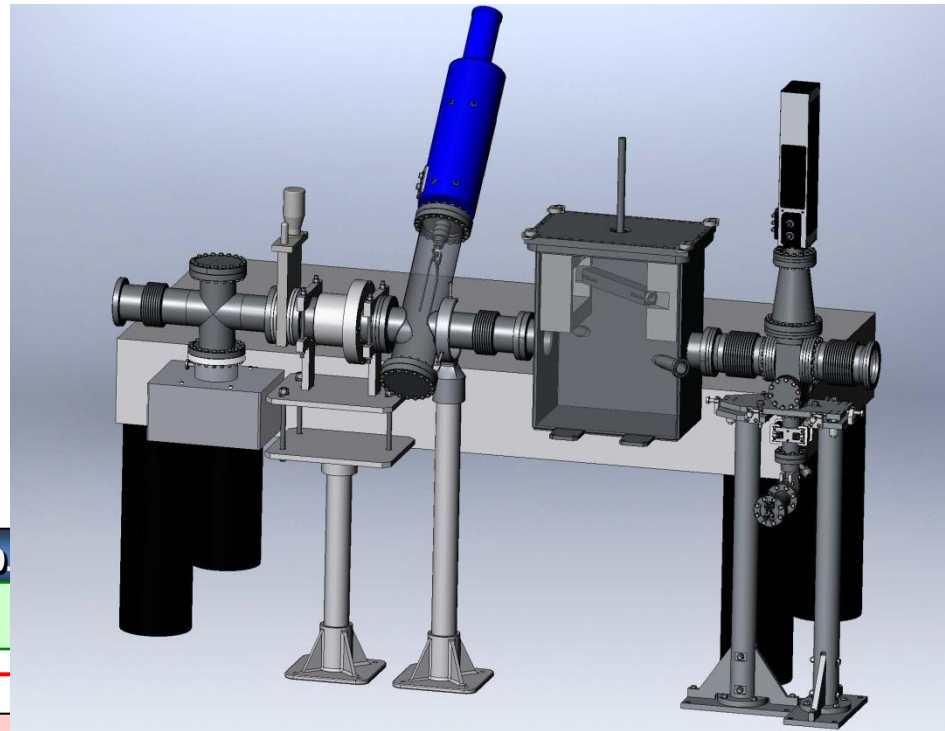
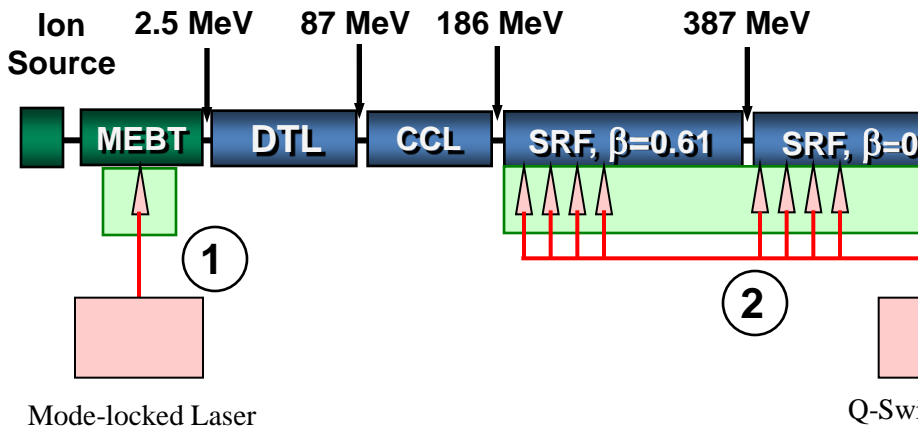
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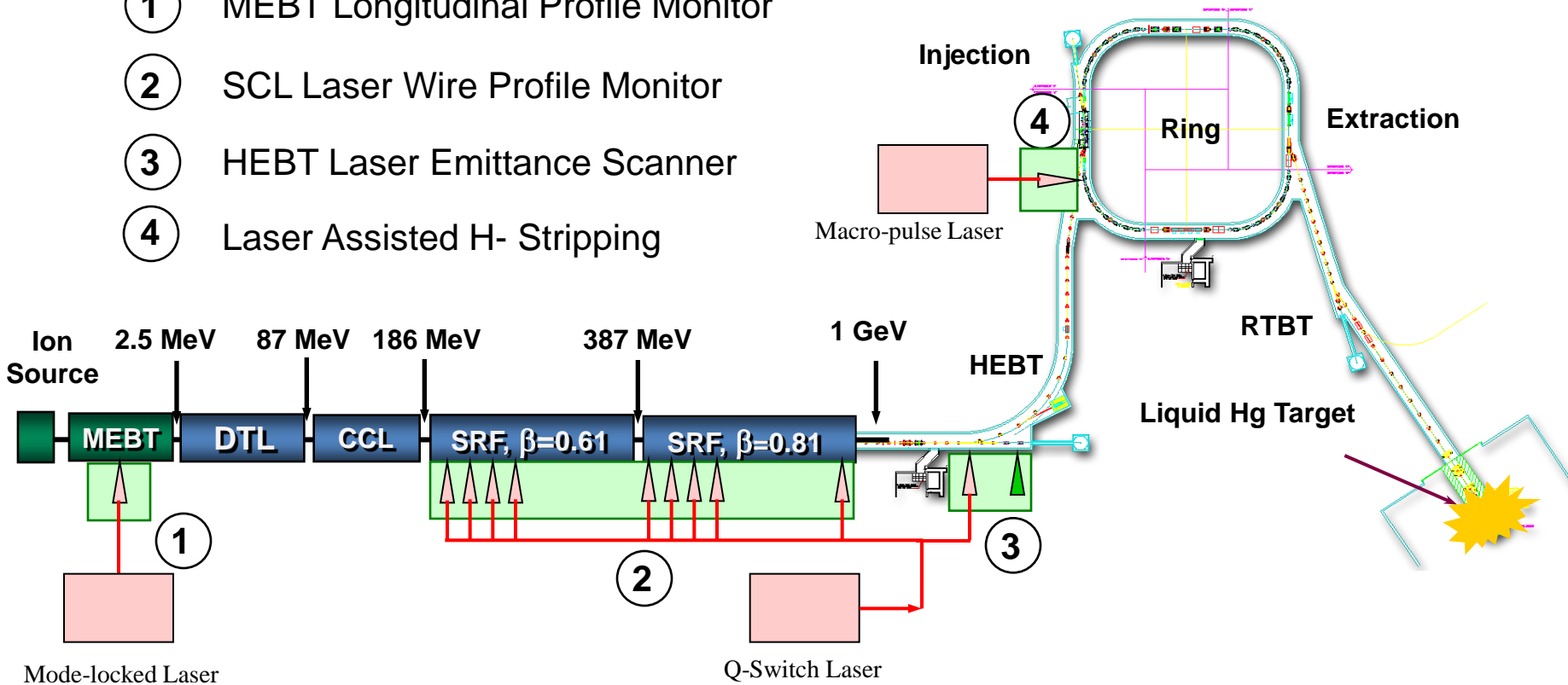
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Commissioning Experience

Item	Findings	Solution
Laser Transport Line	Drift and vibration	Beam stabilization using active feedback Optical fiber based transport line (for low power)
Laser fluence	Over focusing of laser beam caused vacuum window breakdown	Avoid beam collimation optics close to measurement station. Ensure laser fluence below 1 J/cm ² .
Influence on beam	Electron collection magnets can cause tiny beam deflection	Correction magnet installed Orbit correction
Radiation hardness of laser	Laser driver (> 6 m from beam line) damaged in 1-2 days Unclear about laser head	Laser should be located outside the beamline for hadron machine
Image sensors	Gigabit Ethernet cameras (> 1.5 m from beamline)	Have to replace every 1-2 years
Motion control	Stepper motor (~ 30 cm from beam line); Picomotor actuators (1.5 m from beamline)	Stepper motors are very robust Open-loop picomotors have to be used

SUMMARY

- **World-first demonstration of simultaneous H- beam profile scan using a single laser source.**
- **The system has been brought to operation level – a single push-button initiates profile scan at 9 locations of SCL (corresponding to energy levels of 200 MeV -1 GeV).**
- **A number of laser based instruments have been commissioned/developed at the SNS accelerator complex.**
- **Laser based beam diagnostics at accelerator facilities is reliable and realistic and provides a useful tool for beam tuning and physics study.**