Development of the Pulse Burst Laser System for NSTX-U: Status

A. Diallo[1], B.P. LeBlanc[1],
D. J. Den Hartog[2], D. Holly[3], M. Borchardt[2], J. Ambuel[3], P. Robl[3], D. Wahl[3], and A. Laundrie[3]

[1] Princeton Plasma Physics Laboratory; [2] University of Wisconsin - Madison; [3] UW-Madison Physical Sciences Laboratory

NSTX-U Collaborator Report
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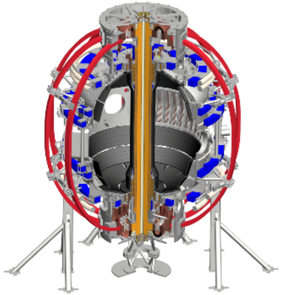
G. Francois, L. Arotcharen and D. Wong from Quantel



Motivation of the ECRP 2013: Edge pedestal structure control for maximum performance on NSTX-U

- Characterize the edge pedestal dynamics on NSTX-U during transient (e.g. ELMs).
  - C-Mod density recovery could not be resolved but the temperature pedestal recovery was in the few ms range. Diallo *et al.*, PRL 2014
  - MAST density pedestal is observed to recover in 5 ms. Diallo *et al.*, EPS 2014
  - DIII-D showed few ms recovery times of the density and temperature pedestal gradients. Diallo *et al.*, PoP 2015
    - Similar observations on AUG A Burckhart *et al.*, PPCF 2010
- Develop actuators for density control in the pedestal.
  - Lithium granule injection (installed) is a good candidate Lunsford (PPPL)
  - AM modulation of RF antenna (to be determined)
- Integration edge actuators and fast Thomson scattering measurements for an attempt of controlling the edge pedestal.

Fast Thomson scattering measurements can be achieved using a pulse burst laser system (PBLS)

- PBLS has been pioneered at MST.

D J Den Hartog, J R Ambuel, M T Borchardt, J A Reusch, P E Robl, and Y M Yang
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- On NSTX-U, we plan to **A** extend the pulse duration and, **B** add a baseline mode to increase the regular (60 Hz) TS temporal resolution.

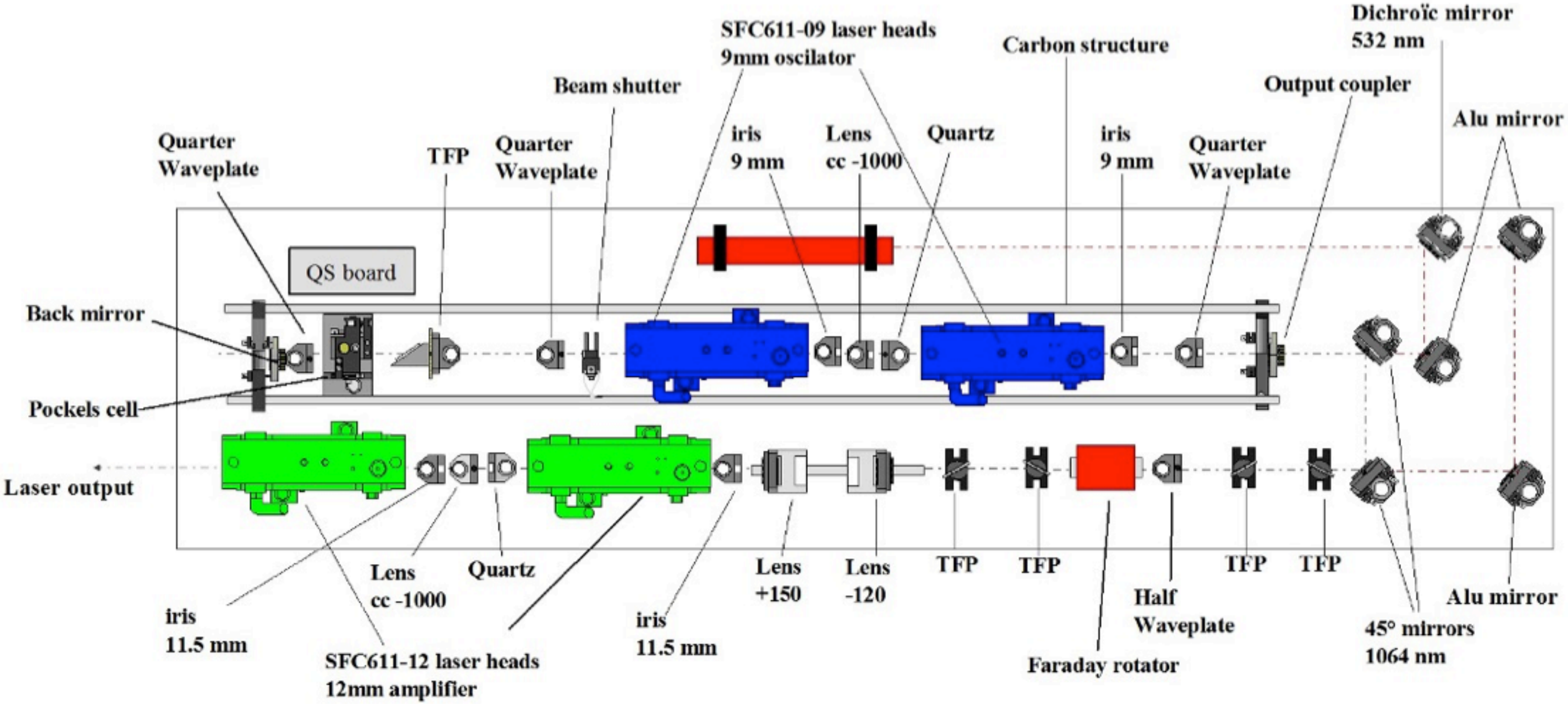
- PBLS will offer new measurements capabilities to tackle a wide range of physics.
  - ELM onset physics.
  - MHD, *e.g.*, kink and tearing modes.
  - L-H transition.
  - Probe the electron distribution induced by RF.
  - Fast ion physics, *e.g.*, density and temperature displacements induced by TAE modes.
  - Edge turbulence.
  - Others….

PBLS - Design specifications

- Pulse energy ⇛ 1.5 J per pulse
  - Pulse width ⇛ 10 ns (FWHM)
  - Beam diameter ⇛ 10 mm @ 0.5 mrad
- Three modes of operation
  - Base mode @ 30 Hz to be compatible with the current NSTX-U rep rate
  - Slow burst mode: 1 kHz rep rate for 50 ms
  - Fast burst mode: 10 kHz rep rate for 5 ms.

  (limited by thermal lensing)
- Take advantage of Nd:YAG rods thermal inertia

Quantel laser head provides large diameter rods to increase the thermal inertia

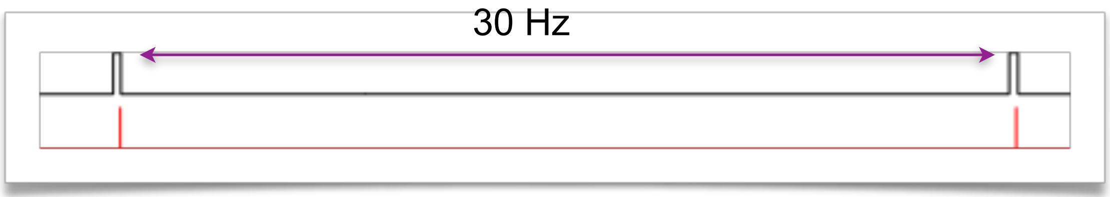


Proposed modes of operation

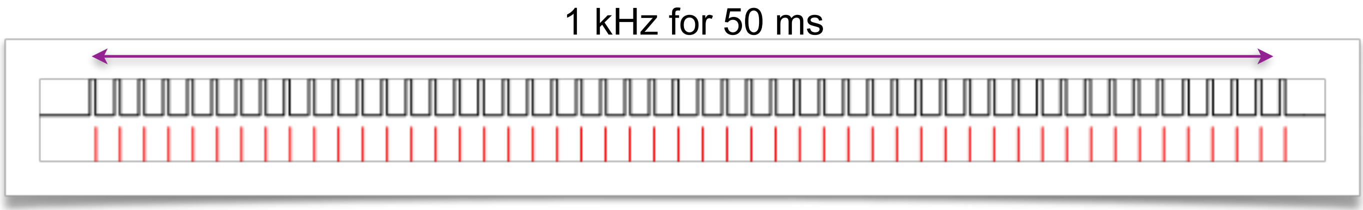
Baseline

Flashlamp

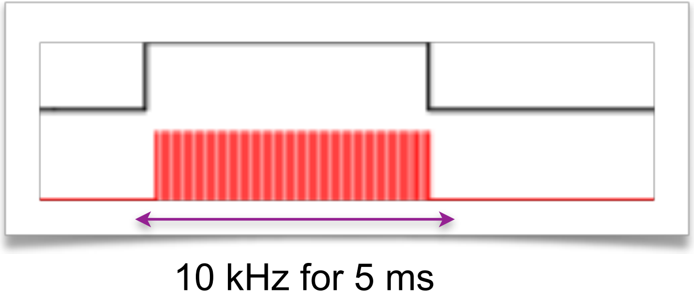
Q-switch



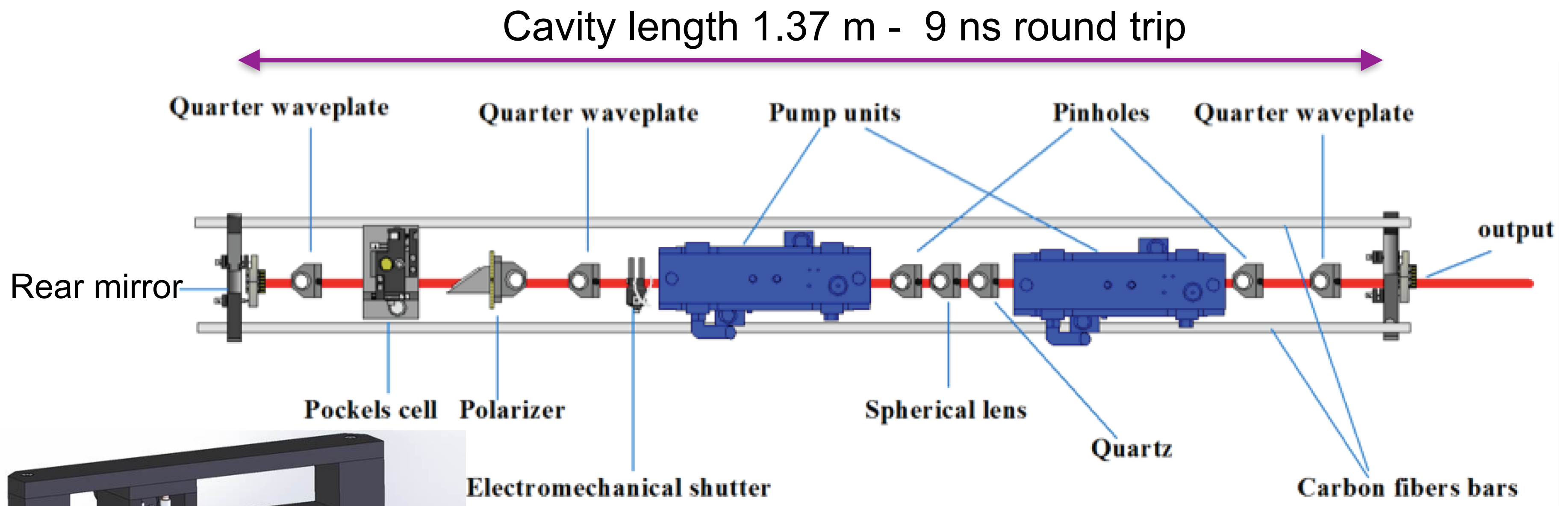
Slow burst

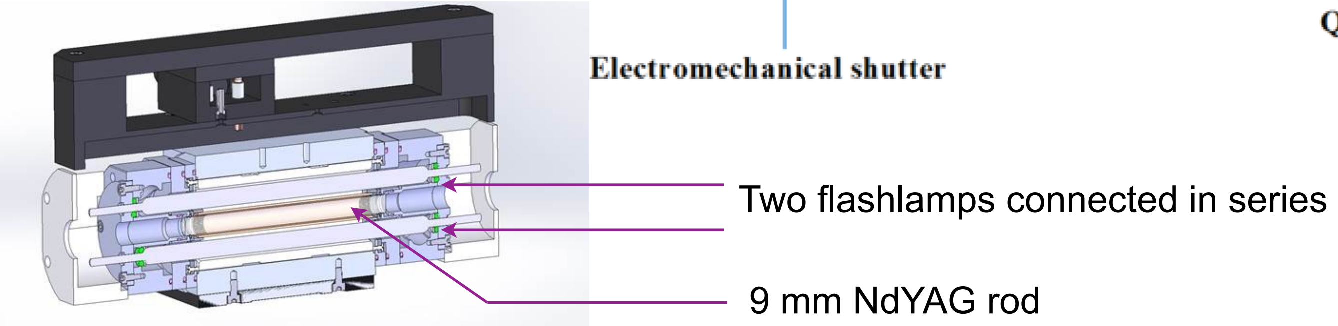


Fast burst



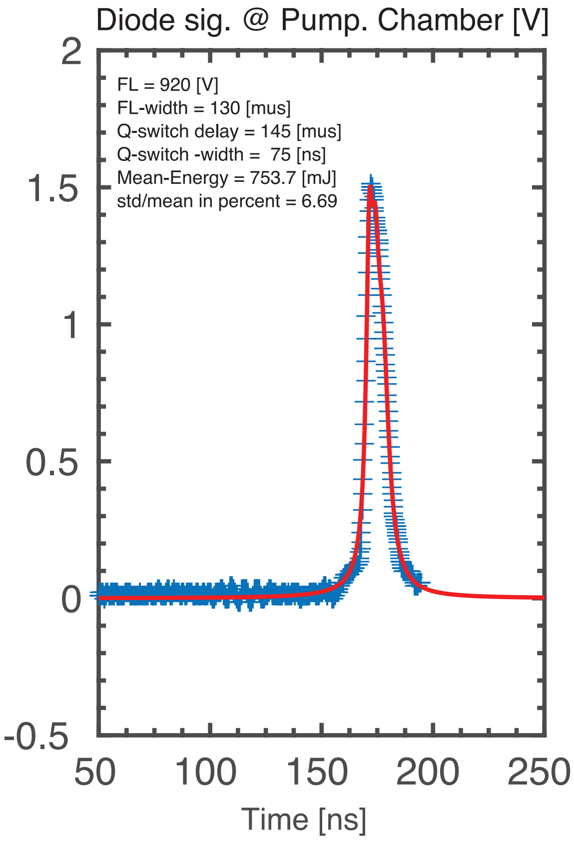
Oscillator cavity is key in defining the pulse shape and laser beam profile quality





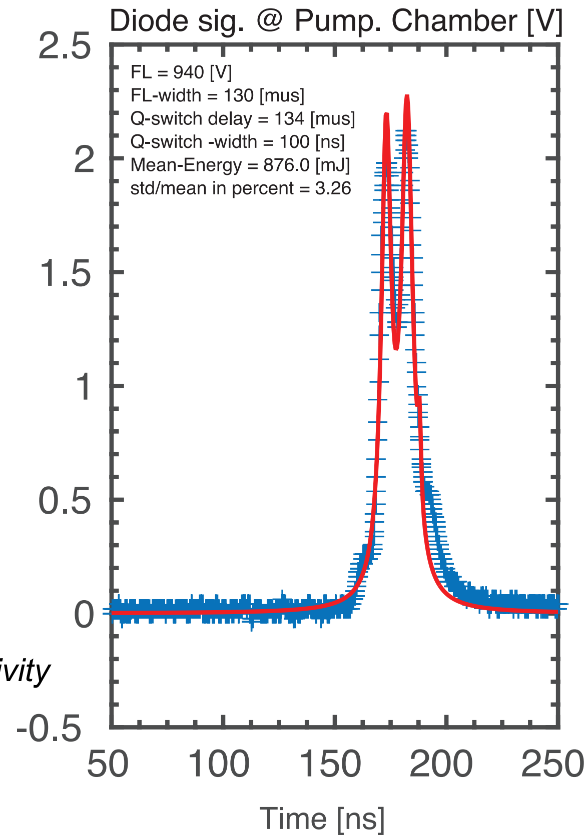
Cut of the pumping chamber

Two types of pulse shape have been observed at the exit of the oscillator

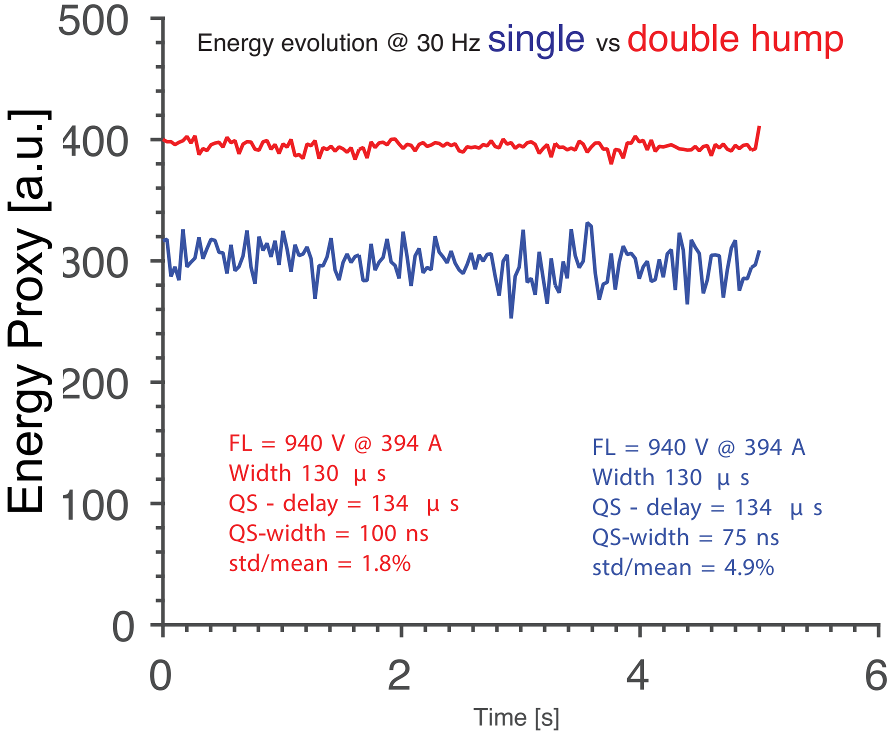


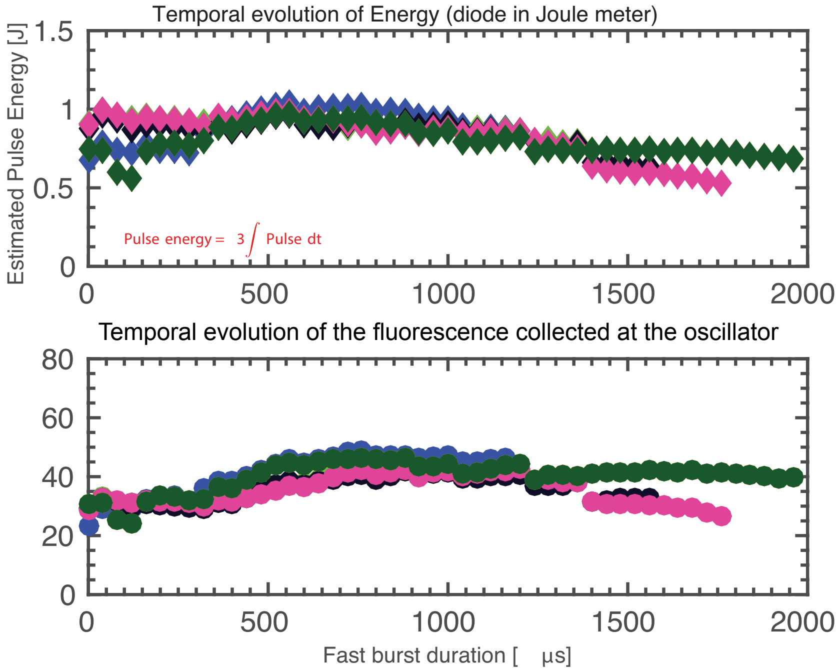
- Single and double hump pulses
- What are the implications for the NSTX-U TS analysis?

Laser head can in principle produce a stable single-hump pulse by optimizing the oscillator output coupler reflectivity (subject of future upgrade)

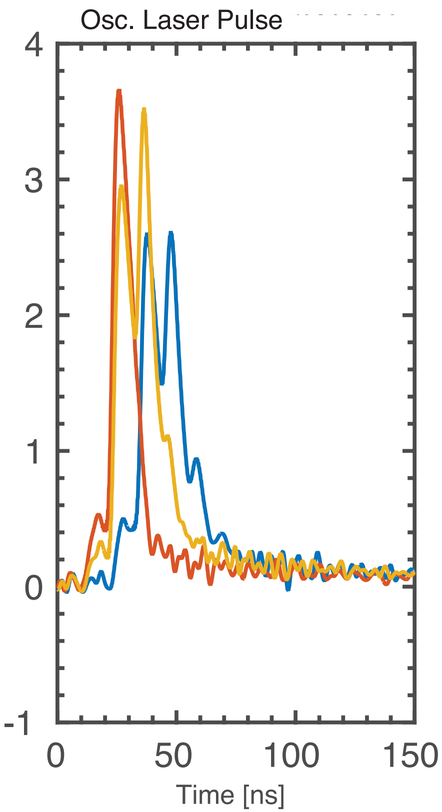


Pulse energy evolution for base and slow burst mode at the oscillator

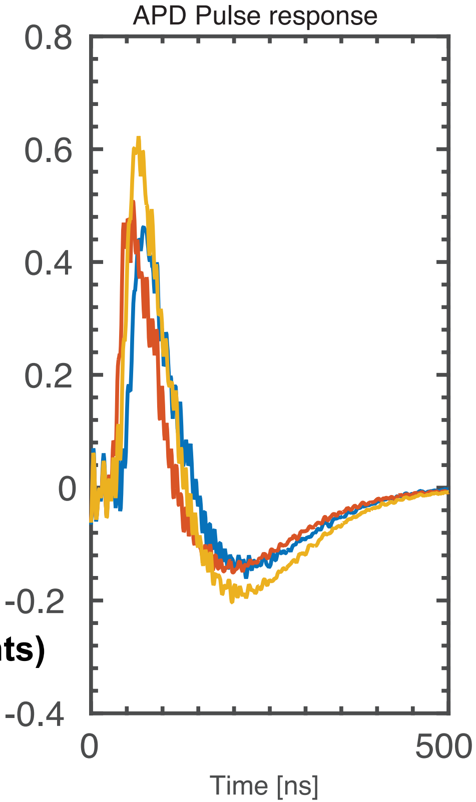




APD preamp response is satisfactory with double hump laser pulse shape



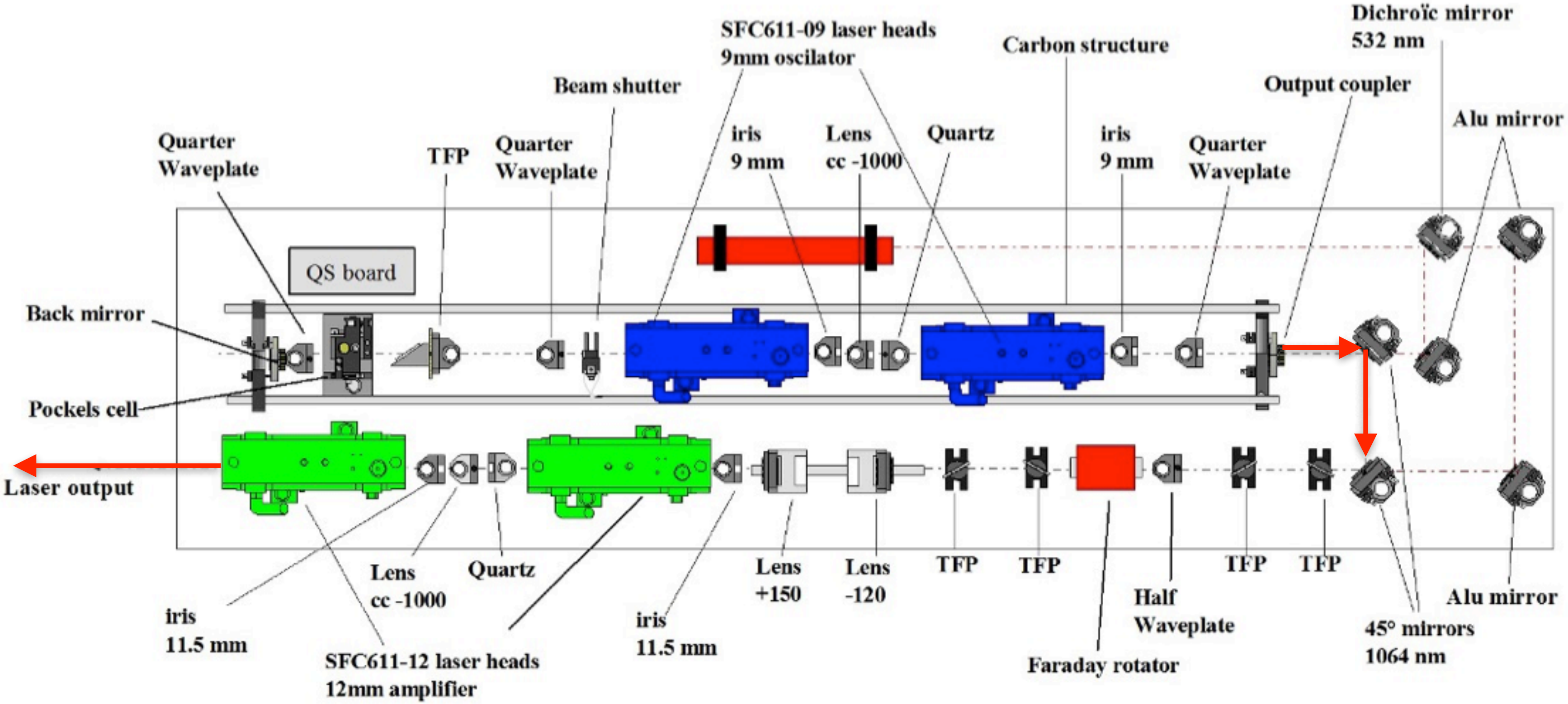
Given the small pulse to pulse variability, we chose to operate the oscillator in the double hump mode



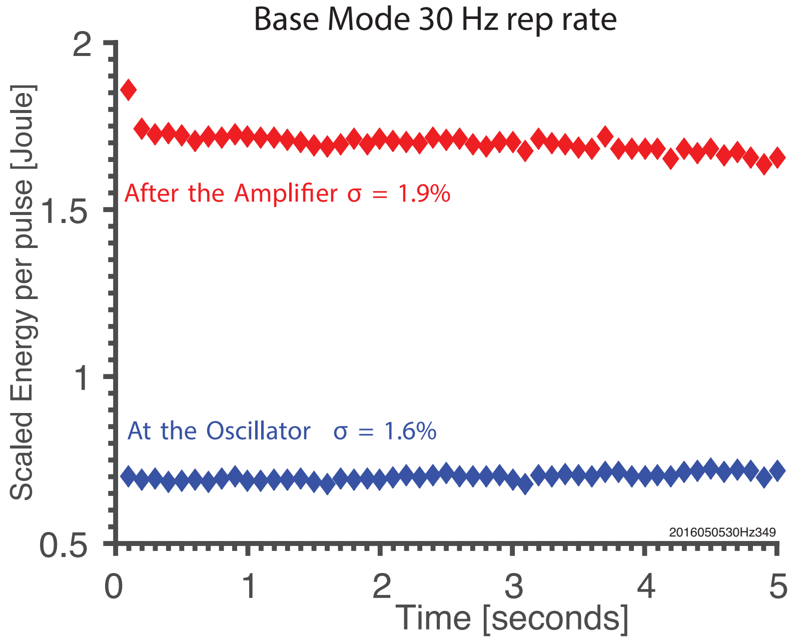
Current data acquisition system is not **adequate** for slow and fast burst pulse detection

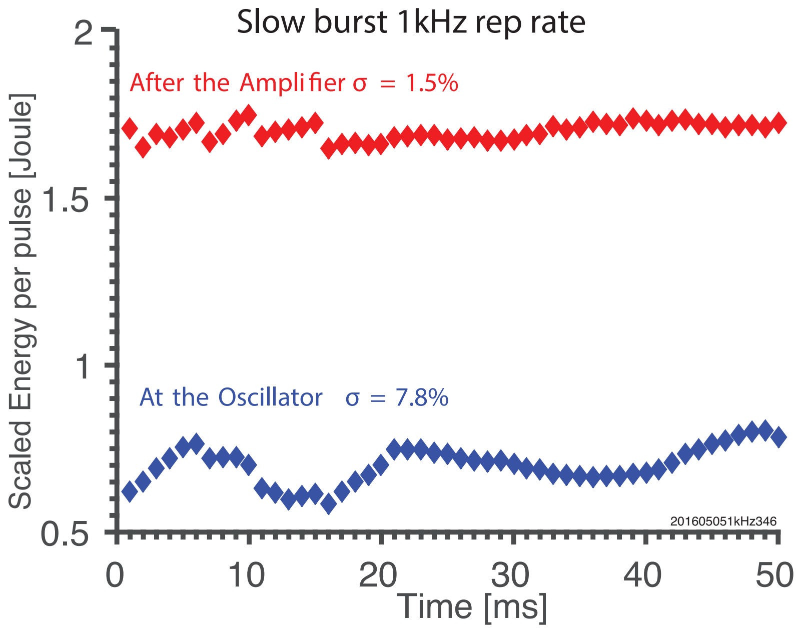
Addition to fast acquisition 60 channels (10 radial points) system (Struck system) which was tested!

Pulse shape selected for the three operation modes: Next step: Beam amplification

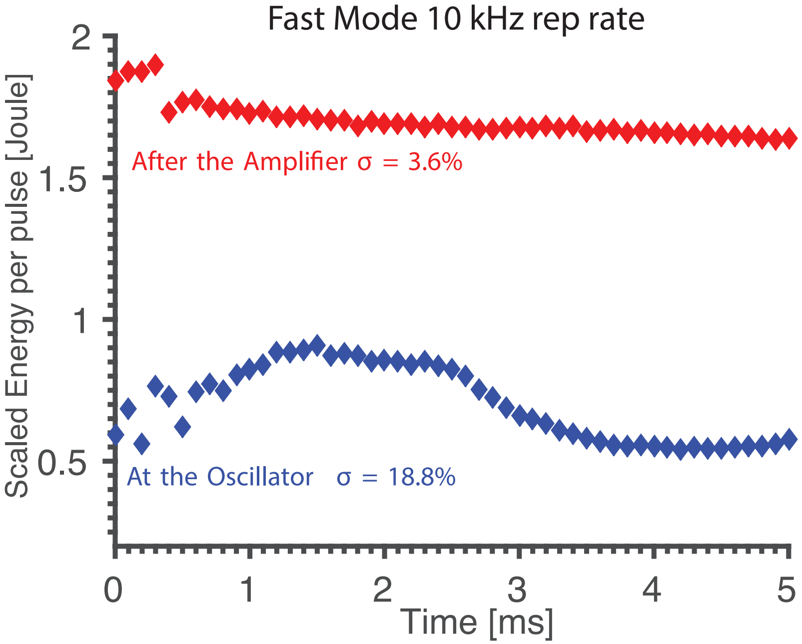


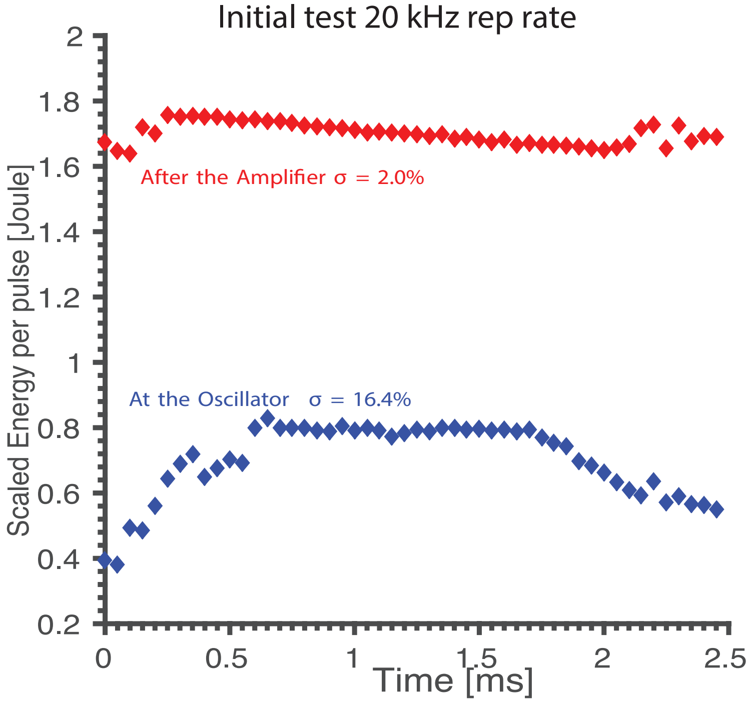
Energy levels needed for the base and slow burst modes were achieved





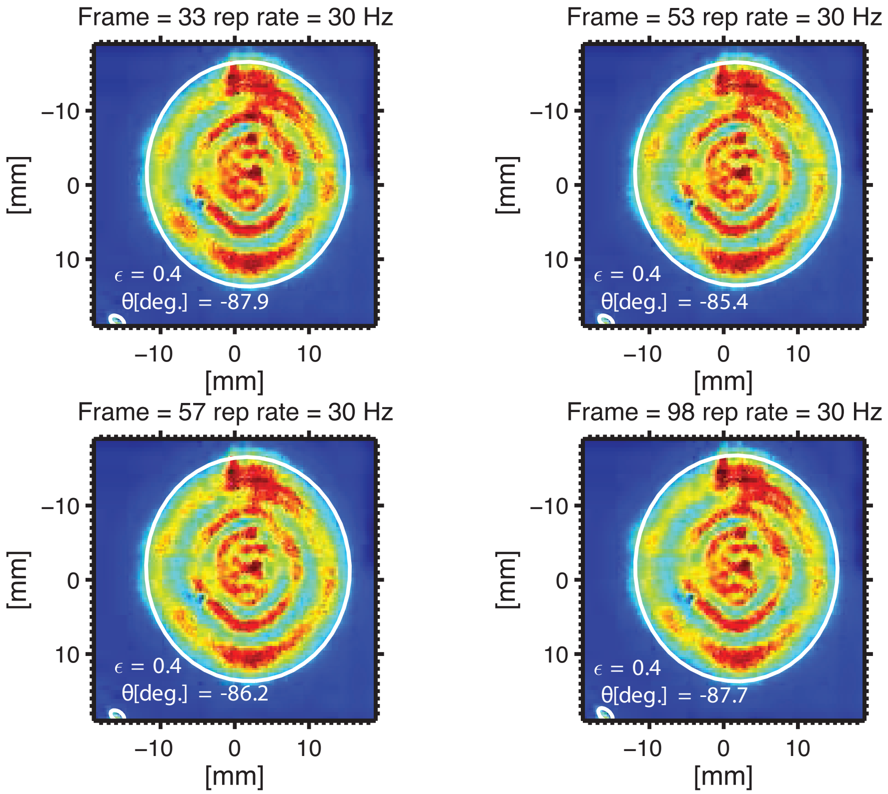
Similar reproducibility are obtained for two fast bursts scenarios: 10 kHz & 20 kHz

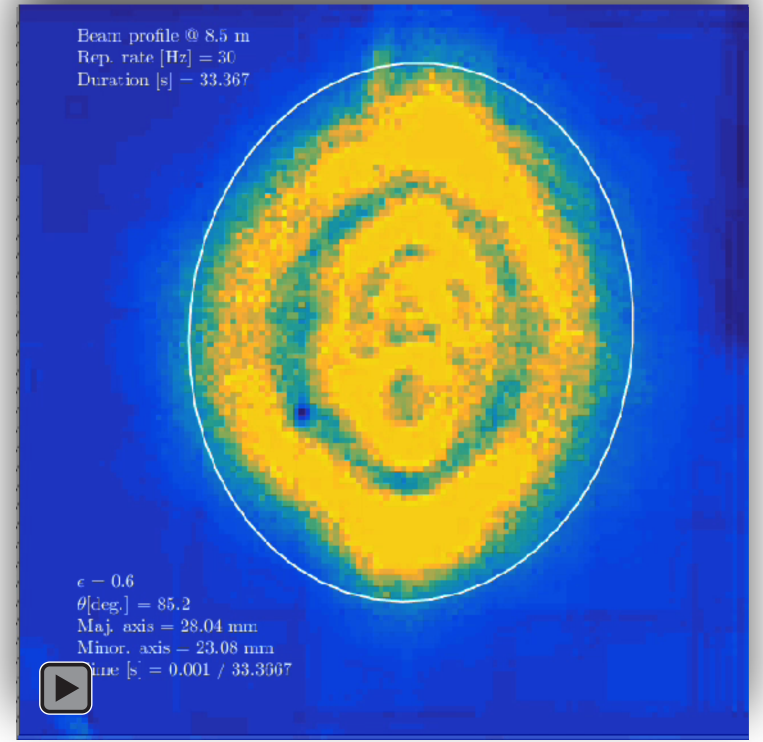




Base mode exhibits good beam profile far field stability

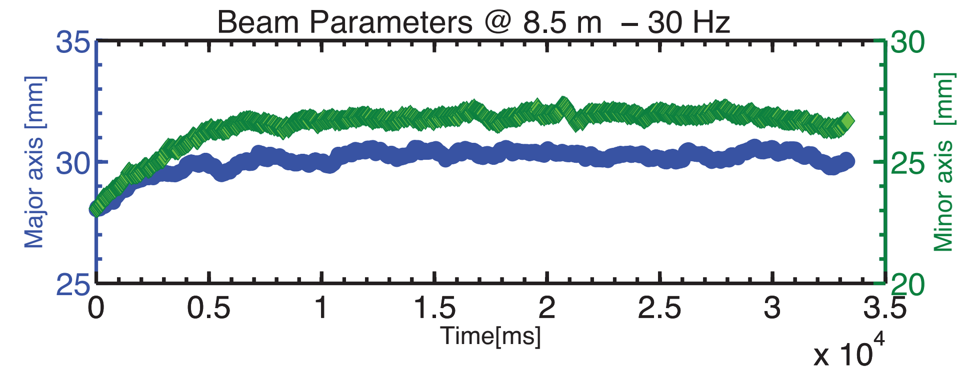
(Beam imaging at 8.5 m)

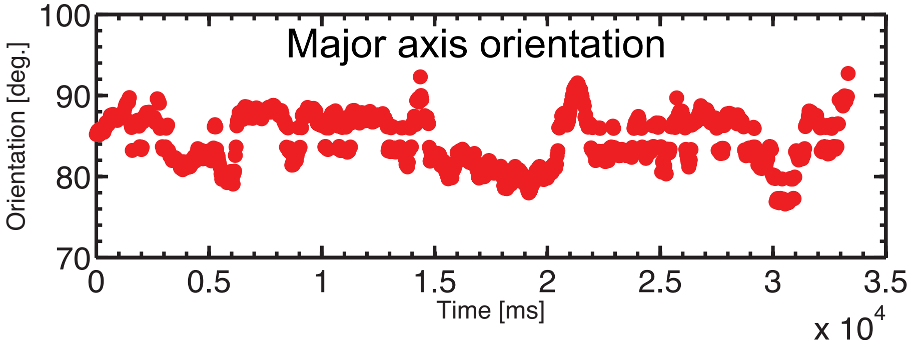


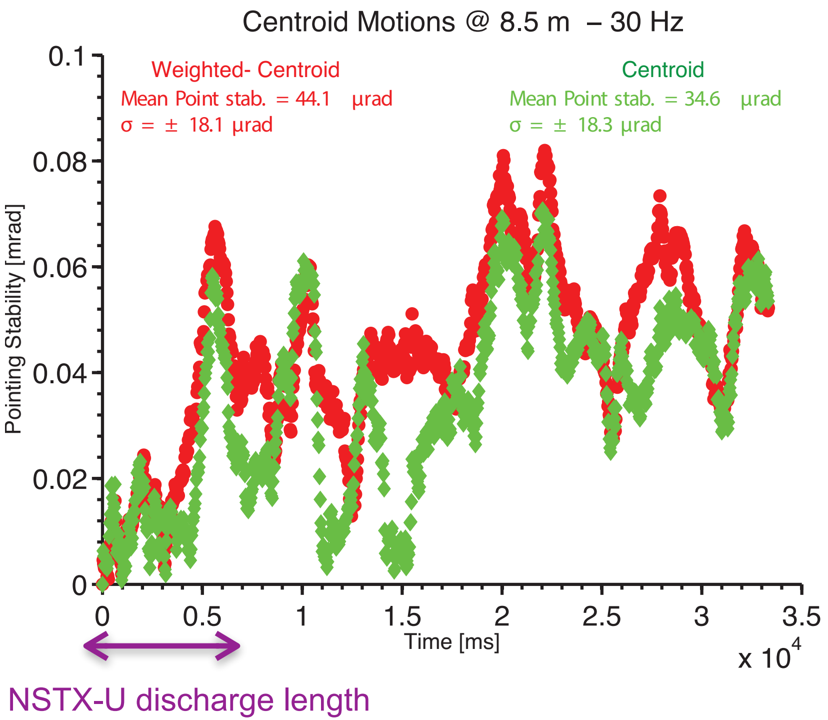


Thanks to R. Perkins, M. Jaworski, F. Scotti for the initial assistance in operating the camera.

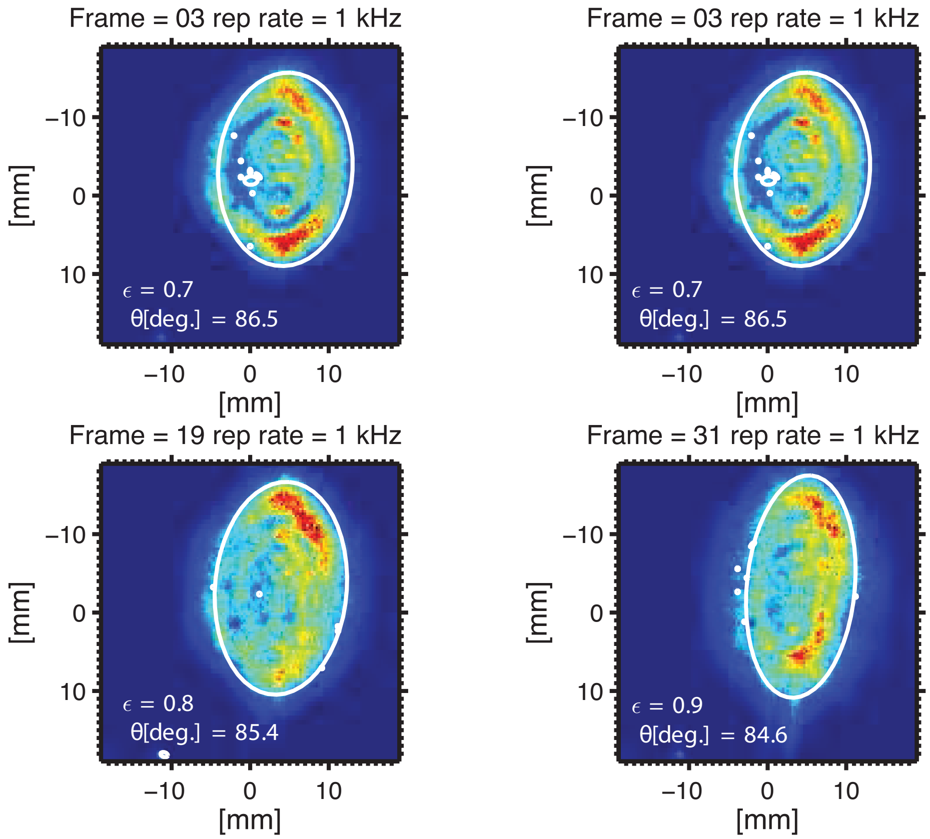
Summary of beam parameters in far field field for base mode: Major (vertical) axis and orientation, minor (horizontal) axis, pointing properties

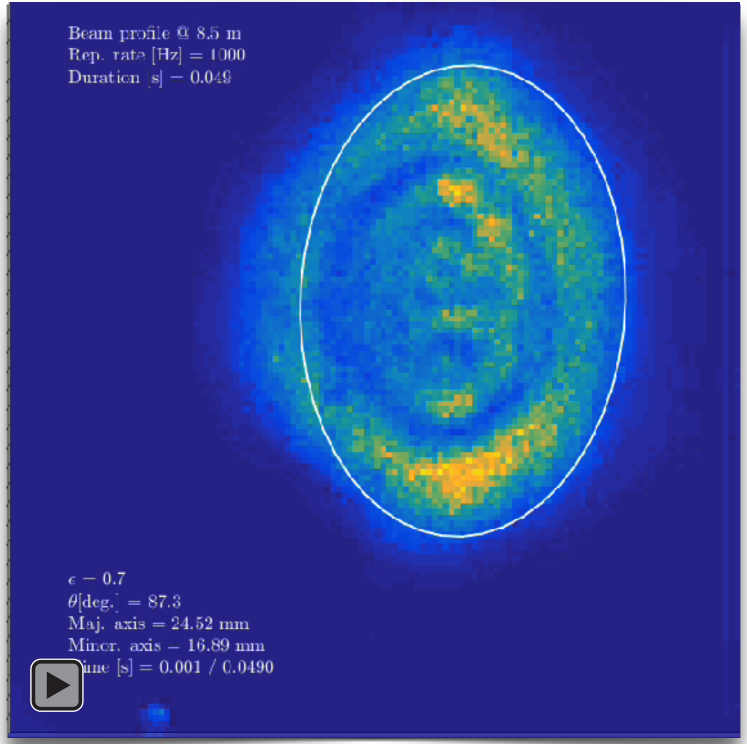




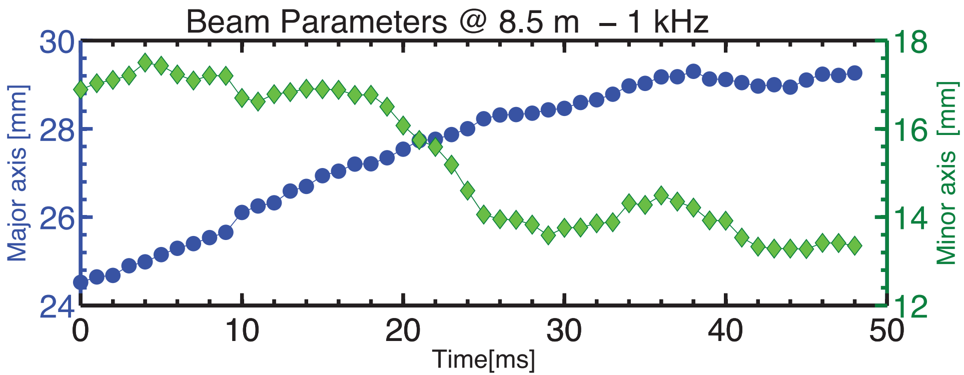


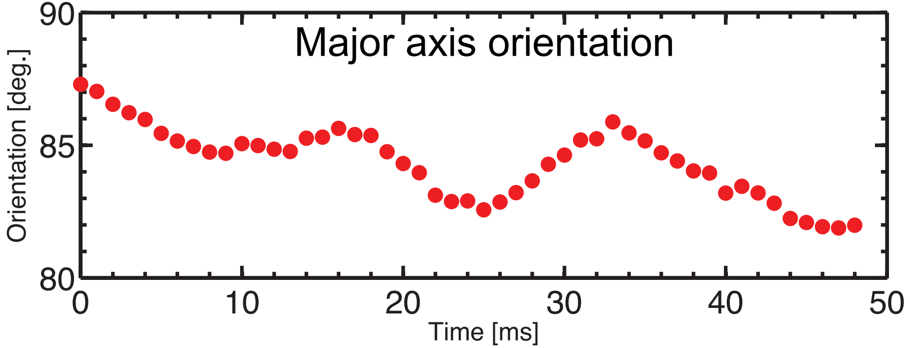
Slow burst mode exhibits an elongated beam profile in the far field *(still under investigation)*

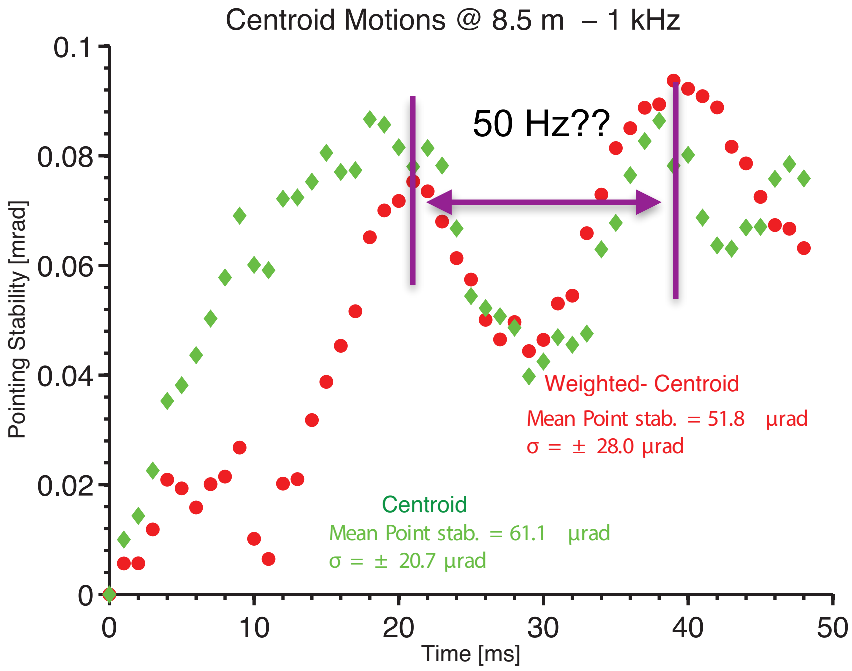




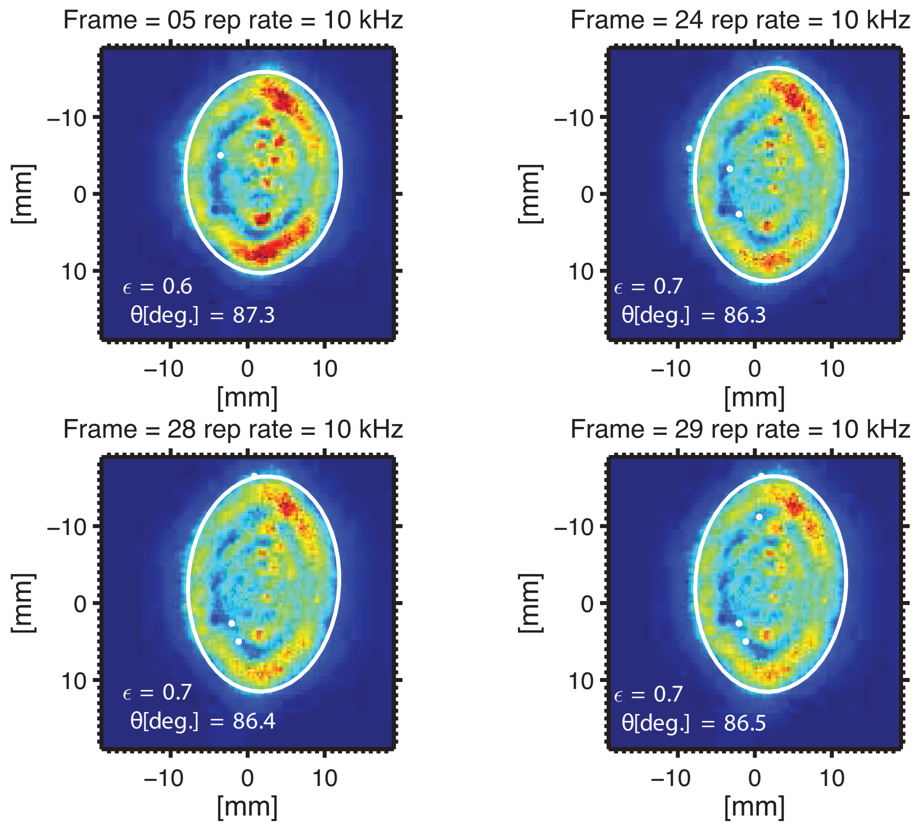
Summary of beam parameters in far field field for slow burst
Major (vertical) axis and orientation, minor (horizontal) axis, pointing properties

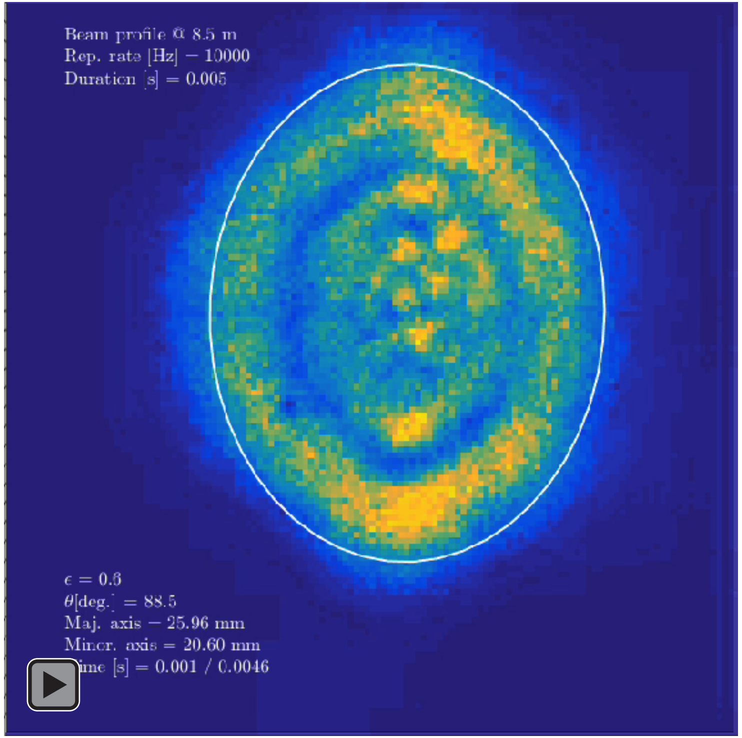




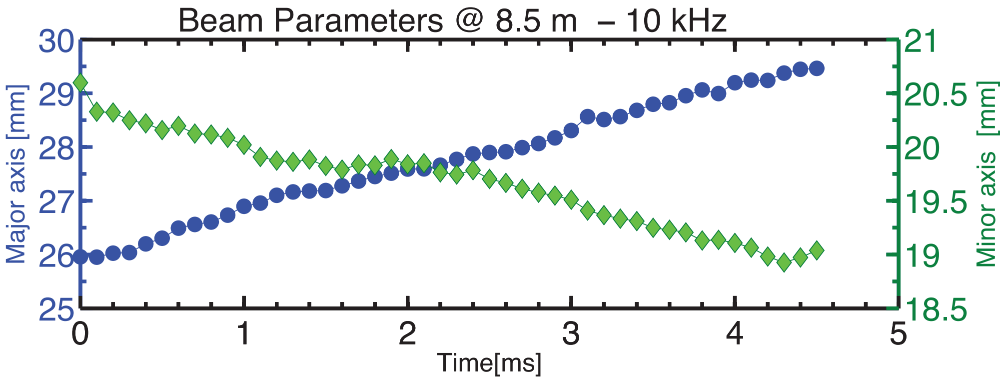


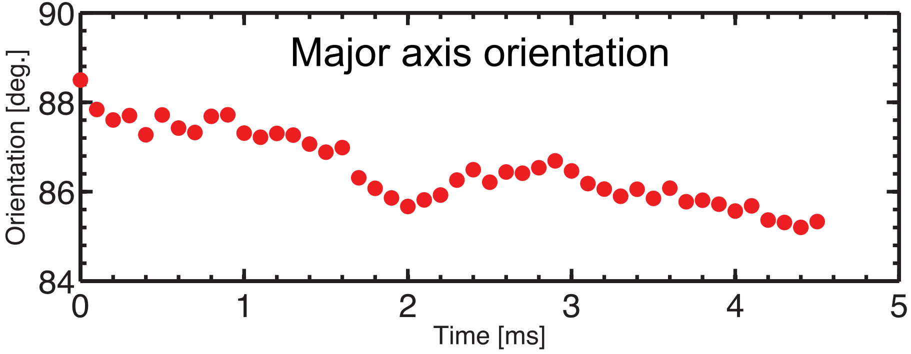
Fast burst mode has acceptable far-field beam properties

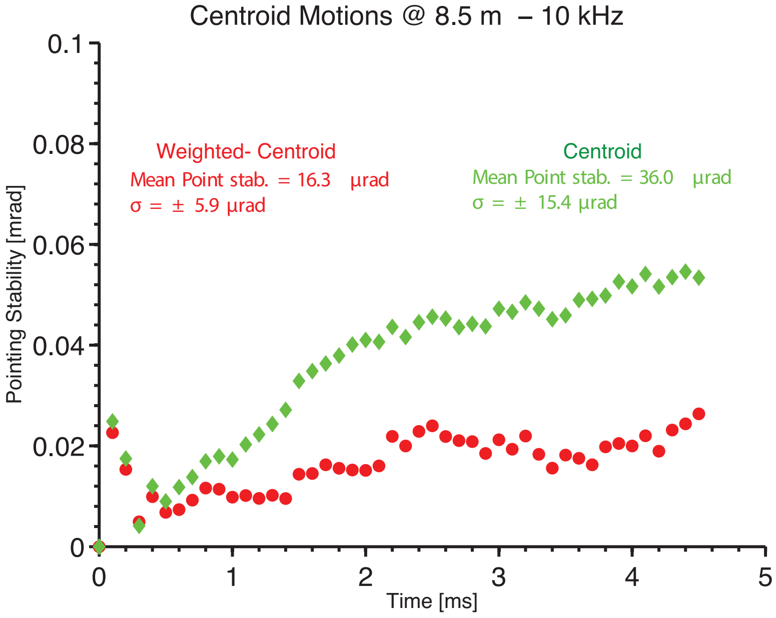




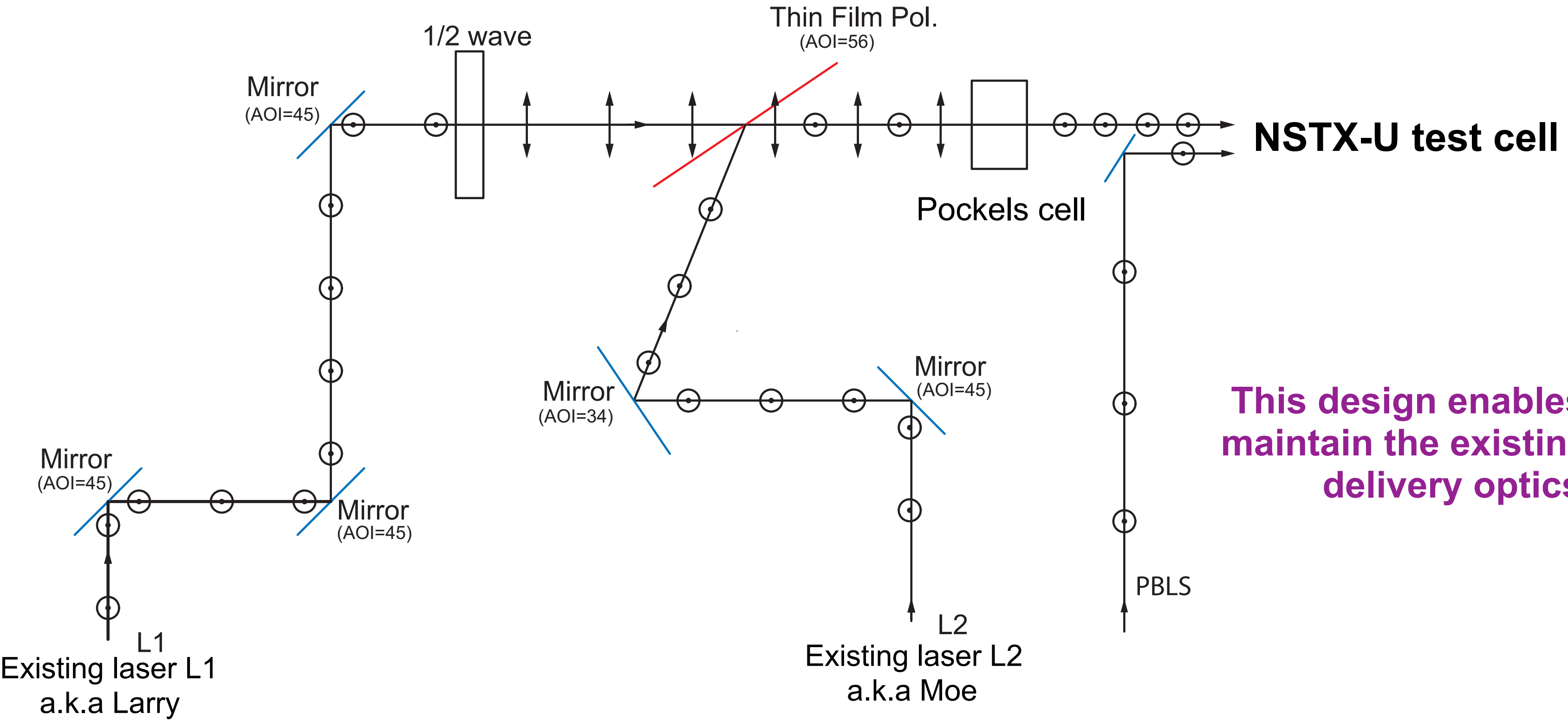
Summary of beam parameters in far field field for fast burst
Major (vertical) axis and orientation, minor (horizontal) axis, pointing properties







Proposed laser beam combining scheme



This design enables us to maintain the existing beam delivery optics.

Summary and action items

- PBLS test activities are on schedule *(delivery before October 2016)*
  - Good progress is being made on the integration of the laser head and power supplies.
  - Ongoing work to fine tune the beam parameters for the three modes of operation in order to facilitate its integration on NSTX-U.
  - Fine tune the laser optics to insure focus spot size and location compatible with existing lasers.
  - Check the time history of polarization orientation.
- Integration on NSTX-U is ongoing
  - Test of the Struck data acquisition is complete.
  - WAF was reviewed on May 13, 2016
  - Laser support structure is ready for fabrication
  - Procurement for the beam combining scheme is ongoing *(Test to begin mid June)*
  - Reconfigure the laser room for PBLS *(Activities to start after the end of run calibration)*
- *Future upgrade: optimizing the oscillator output coupler reflectivity to produce a stable single-hump pulse*