

Status of the CEBAF Photo-Injector Drive Laser System for KLong Beam

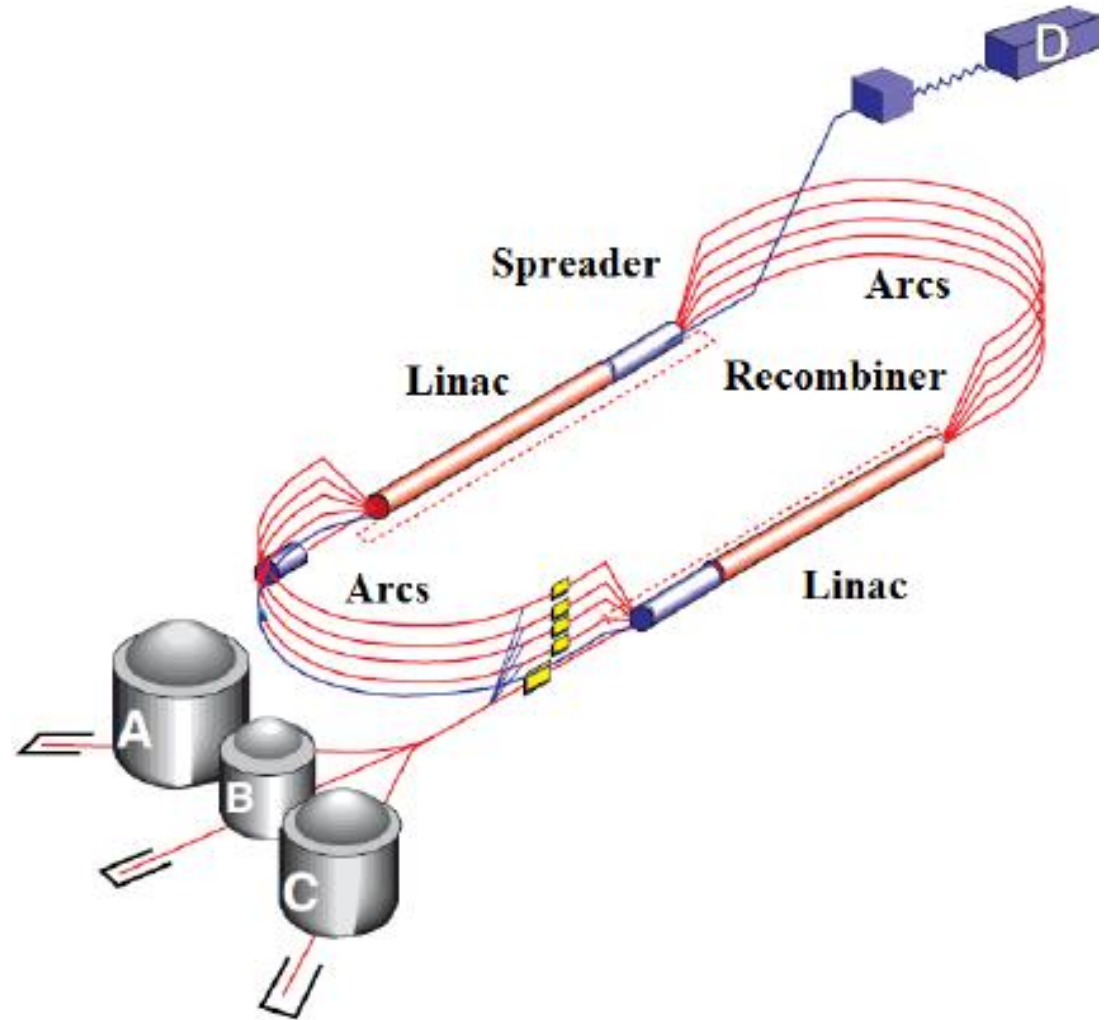


Outline

- Quick Overview
- Recent Tests & Studies
- Summary & Prospects

Shukui Zhang
CIS, Jefferson Lab

September 19, 2023



Review of K-Long Experiment Beam Requirement

- M. Anaryan, *PAC48, JLab, August 11, 2020*

Beam Energy 12GeV, 5uA, bunch spacing 64~128ns

To accomplish physics program, 100 days per LH2 and LD2 is required

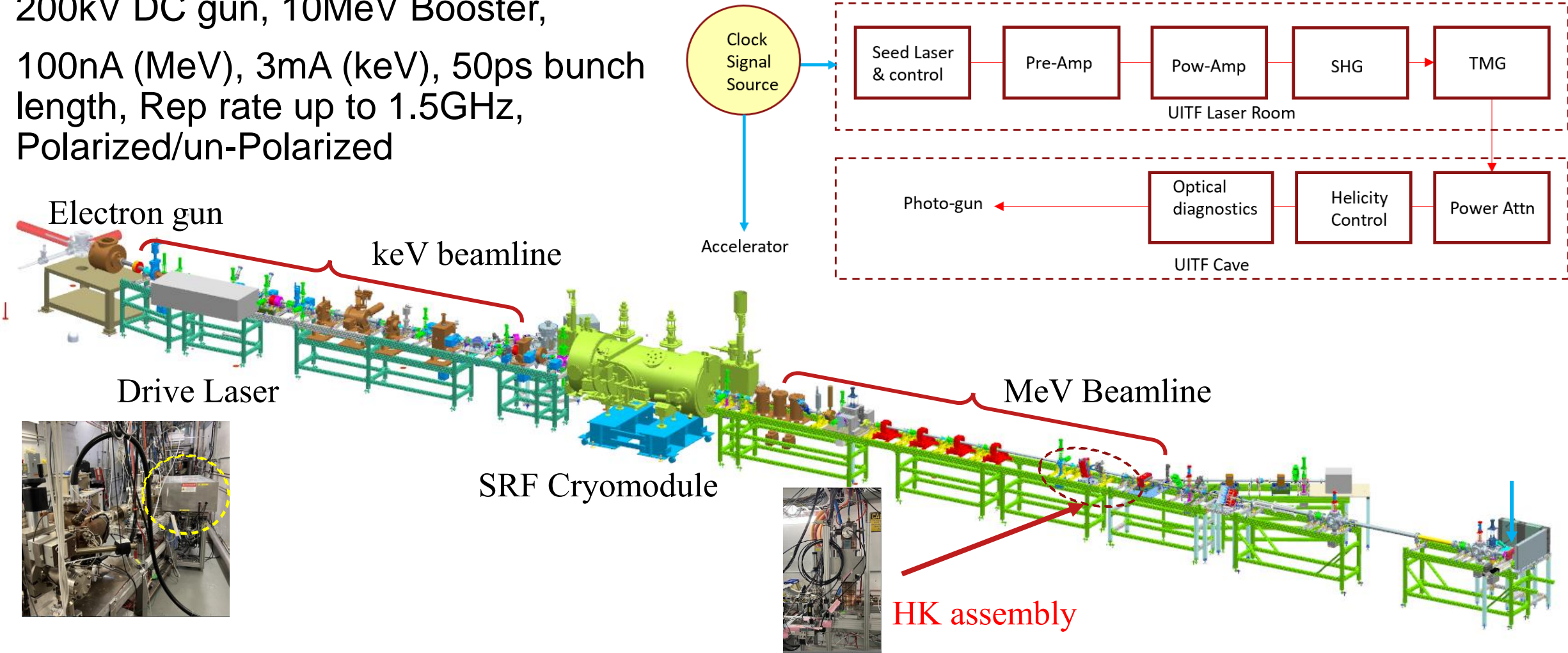
- Requirement on e-beam/accelerator

| Current (μA) | Rep Rate (MHz) | Bunch interval (ns) | Sub-harmonic of 499 MHz | Bunch Charge (pC) | Equivalent 249.5 MHz current (μA) |
|--------------|----------------|---------------------|-------------------------|-------------------|-----------------------------------|
| 2.5 | 15.59 | 64 | 32 nd | 0.16 | 40 |
| 2.5 | 7.80 | 128 | 64 th | 0.32 | 80 |
| 5.0 | 15.59 | 64 | 32 nd | 0.32 | 80 |
| 5.0 | 7.80 | 128 | 64 th | 0.64 | 160 |

- The baseline is 15.59MHz, but 7.8MHz is also desired
- An essential accelerator hardware is *the drive laser*, the existing system is not suitable
 - Past attempts have led to severe damage to multiple laser devices (31MHz in 2015)

What we did: Low Rep-rate Beam Test (UITF & Harmonic Kicker Project, Nov. 2022)

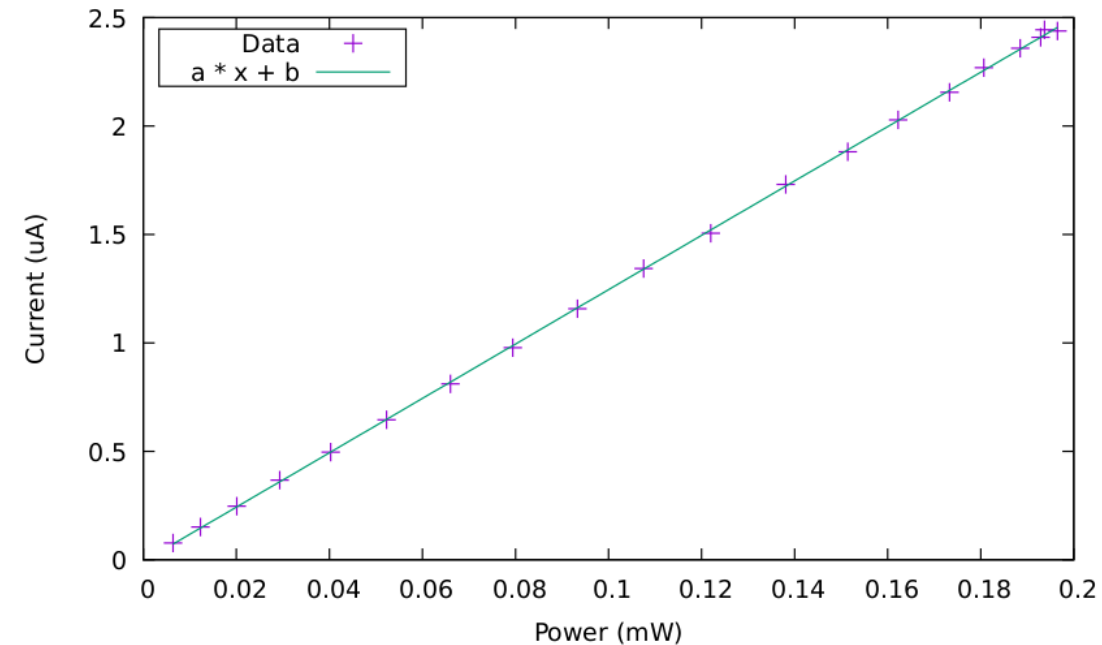
- 200kV DC gun, 10MeV Booster,
- 100nA (MeV), 3mA (keV), 50ps bunch length, Rep rate up to 1.5GHz, Polarized/un-Polarized



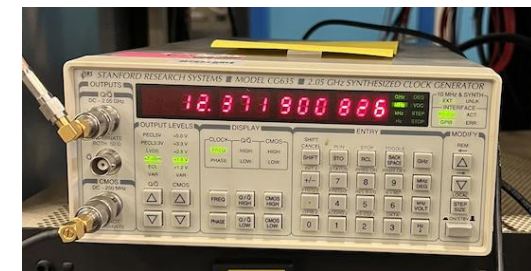
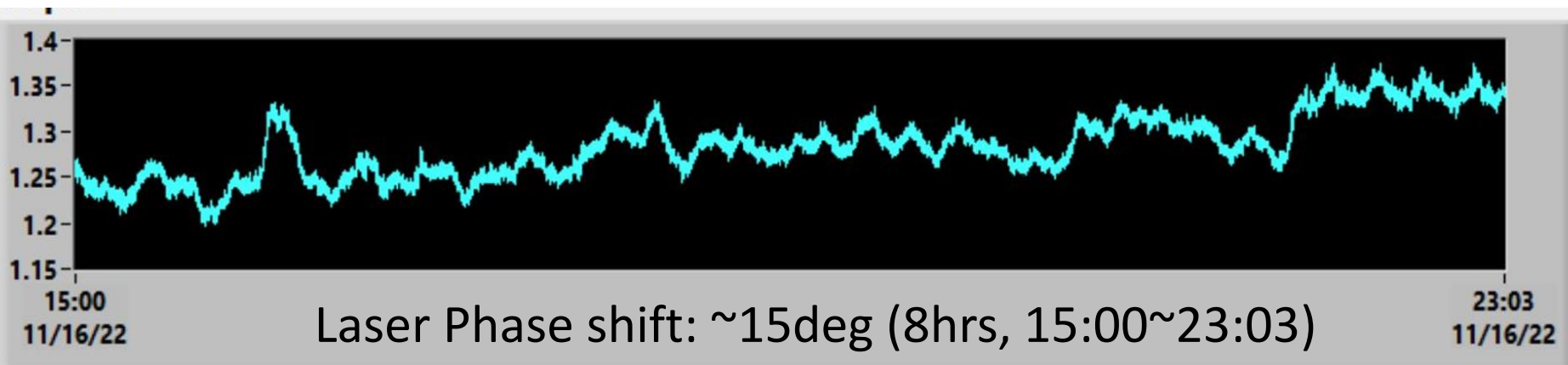
- Harmonic Kicker (HK) requires 12.37MHz bunch rep rate, very close to KL beam requirement

Results & Issues

- 2.5uA at 12.37MHz, 0.2pC/bunch, ~50ps bunch
- Current linearly increase with laser power **12.5 uA/mW, 1pC/bunch, QE~2%**
- **For CEBAF, assuming QE_{min}~0.1%, need <10mW 780nm laser power to run 5uA KL beam current**
- One issue
 - A **phase drift** btw Laser and accelerator observed
 - Investigation shows the culprit is the RF synch device

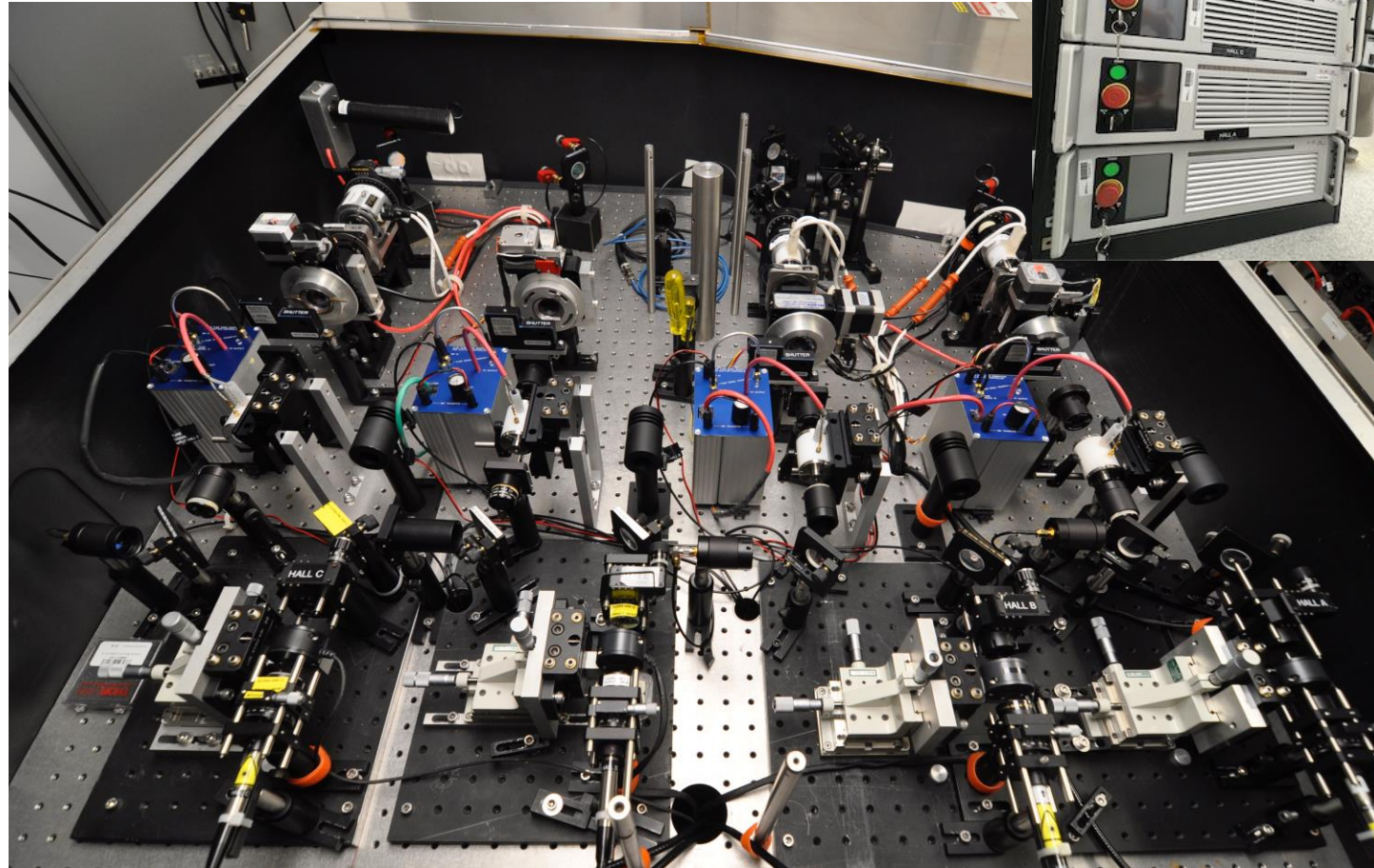


Courtesy M.Brucker

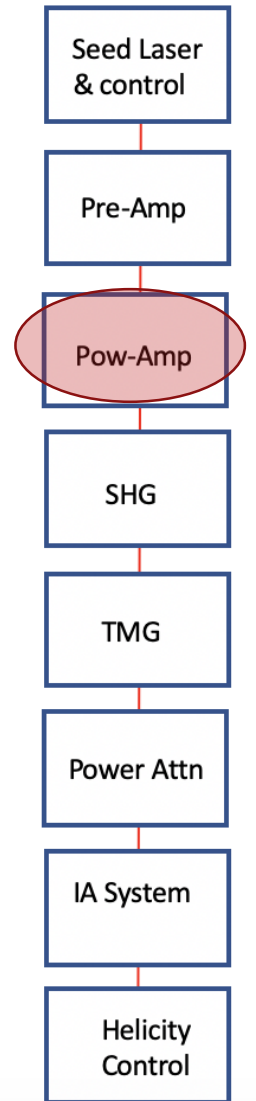


CEBAF Photo-Gun Drive Laser System

- 1.5um Gain-switched seed
- MOPO+SHG
- Polarization/Helicity control
- 499/249MHz CW
- TMD for low duty cycle beam
- 30~50ps pulse
- 780nm/SHG
- mW~100s mW
- 4 independent lasers to 4 Halls (A, B, C, D)

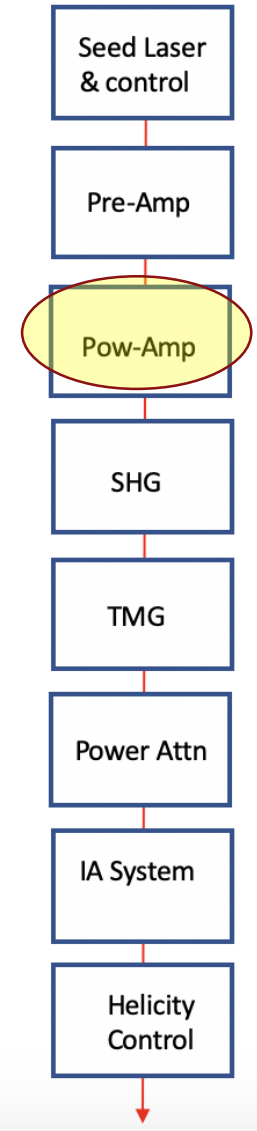
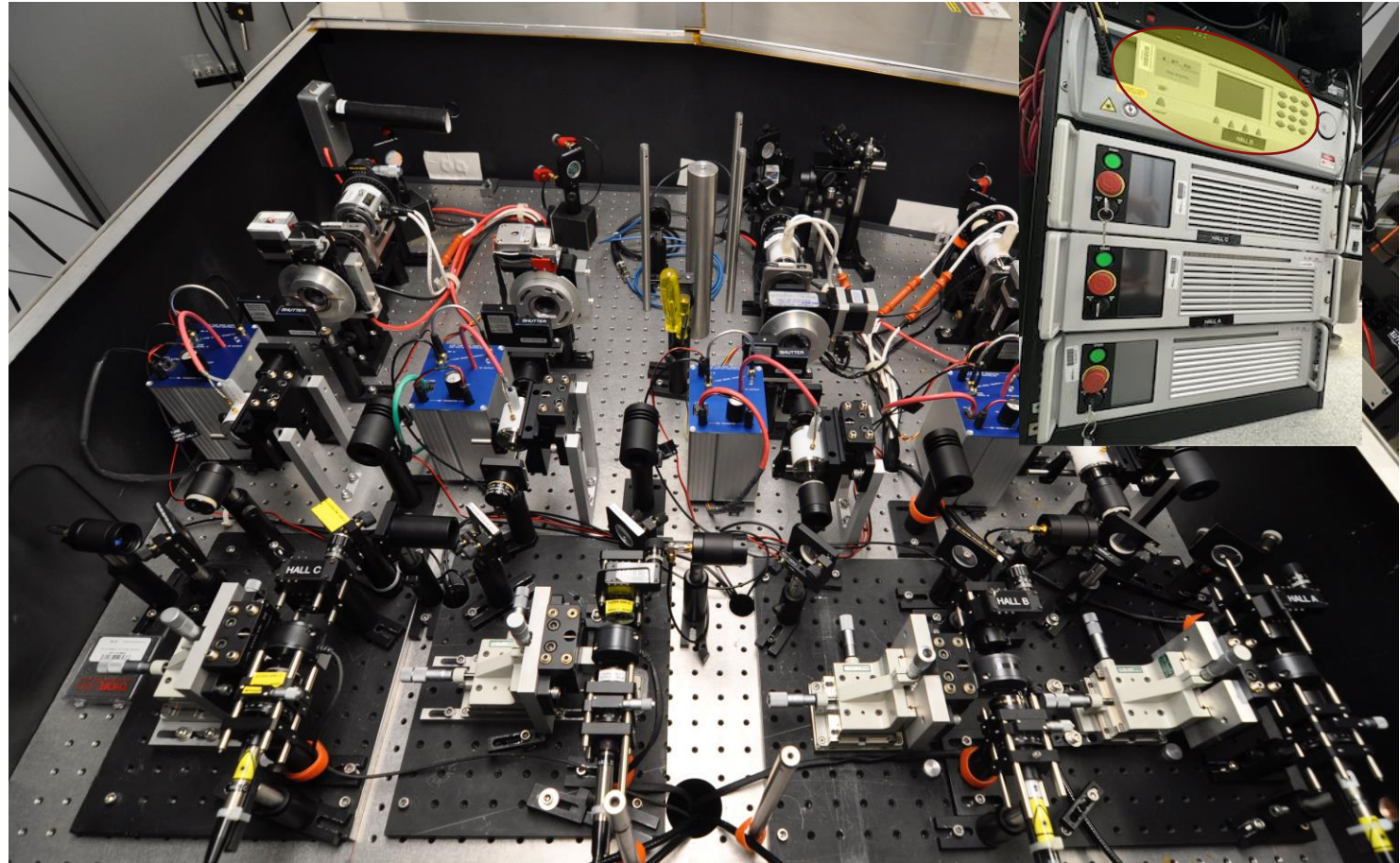


- Relatively low pulse energy
- Not suitable for low rep-rate, high pulse energy operation.



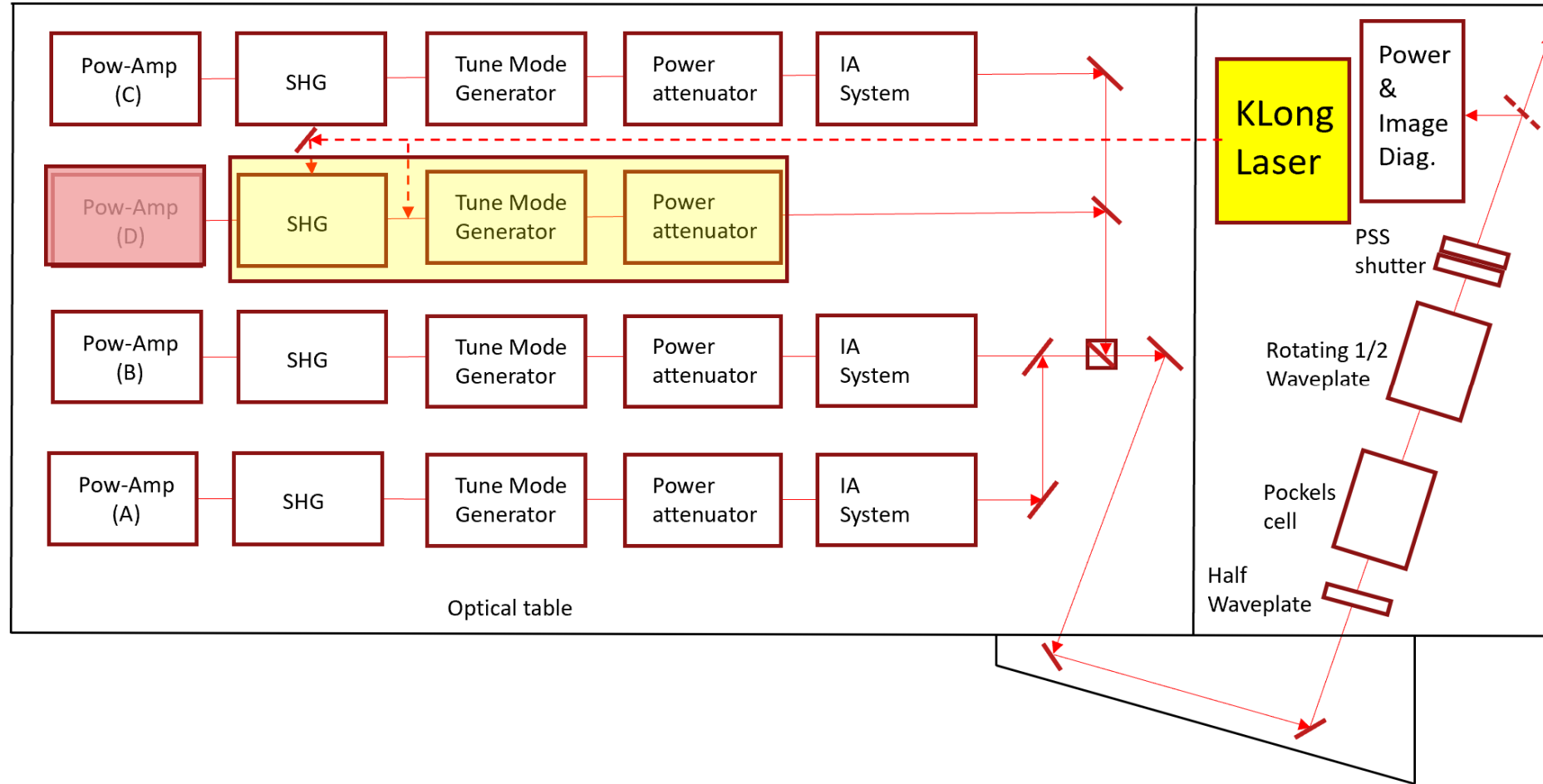
Technical Route to K-Long Drive Laser

- Technical scheme & key components:
 - A new 1.5 μ m Gain-switched seed
 - 15.6/7.8MHz RF signal by dividing 249MHz by 16/32
 - A new high pulse energy laser amplifier
 - Use Existing SHG for 780nm (optional)
 - Use the rest of the hardware downstream of SHG in D laser beam path



To implement at CEBAF

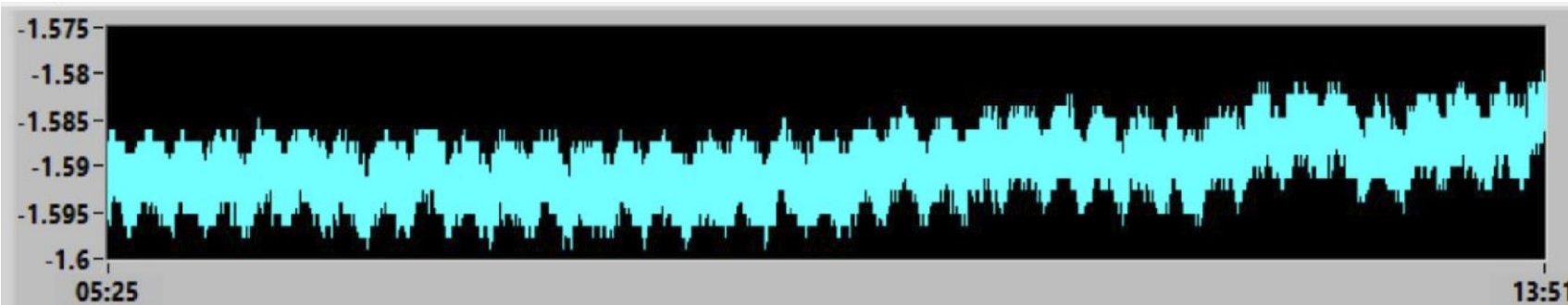
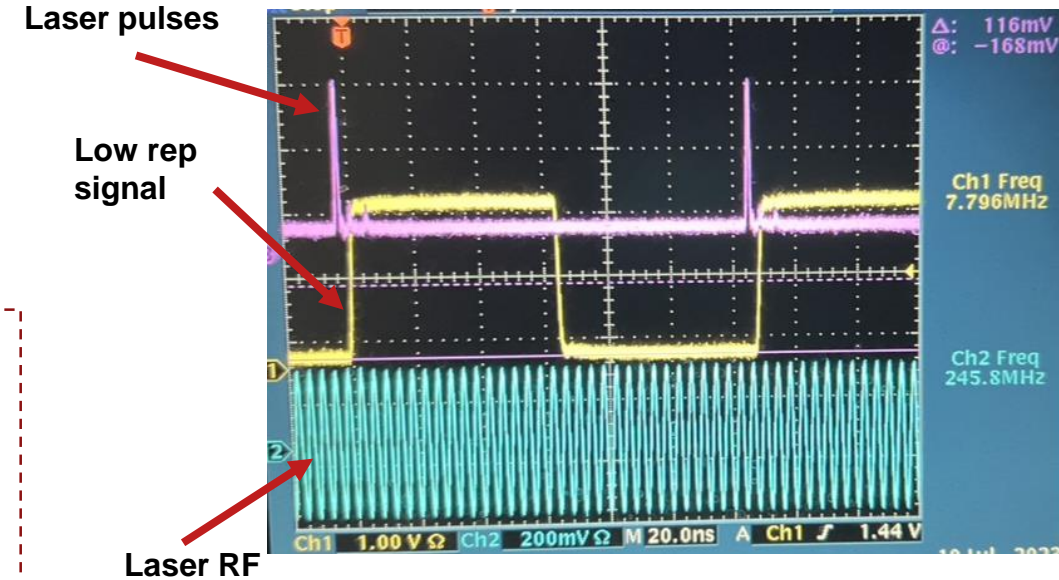
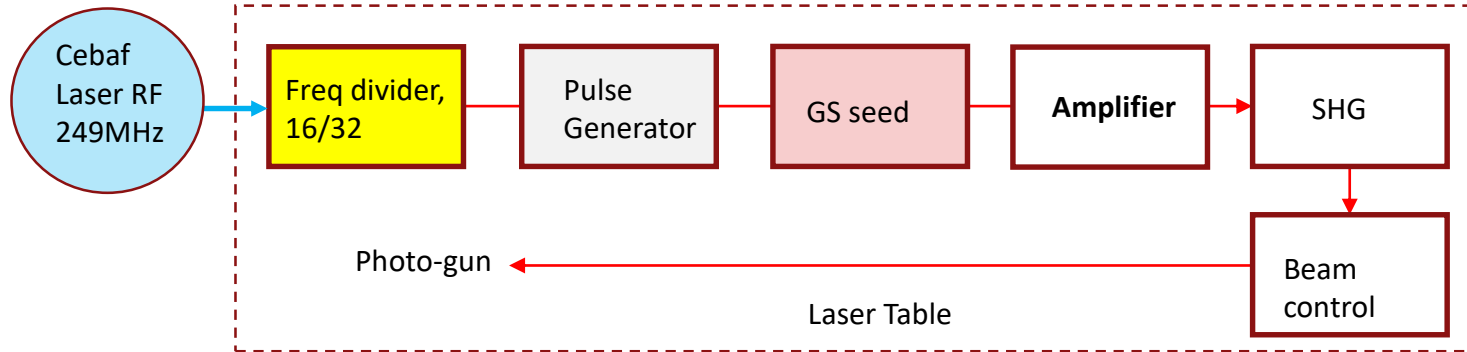
- Add new low freq RF (8 or 15MHz)
- New seed and amplifier
- Use the existing section downstream of the D laser
- Additional optics match



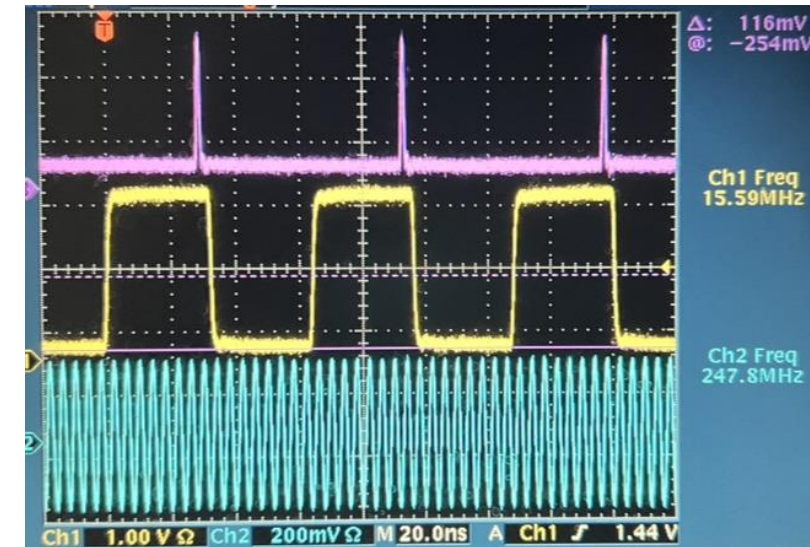
- A new laser amplifier was finally secured.

Low Rep Rate RF & Seed Laser

- Built an frequency division system to generate 15.6 & 7.8 MHz from 249MHz
- Built a new seed laser operating at both 15.6 & 7.8 MHz
- Good long term phase stability verified

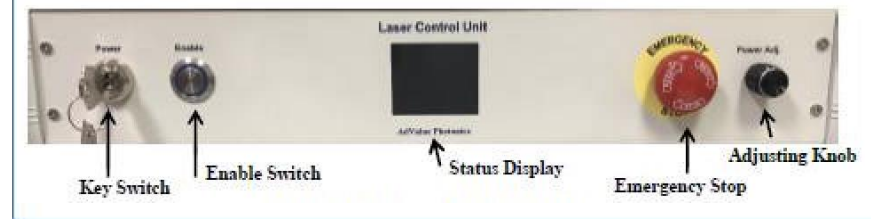
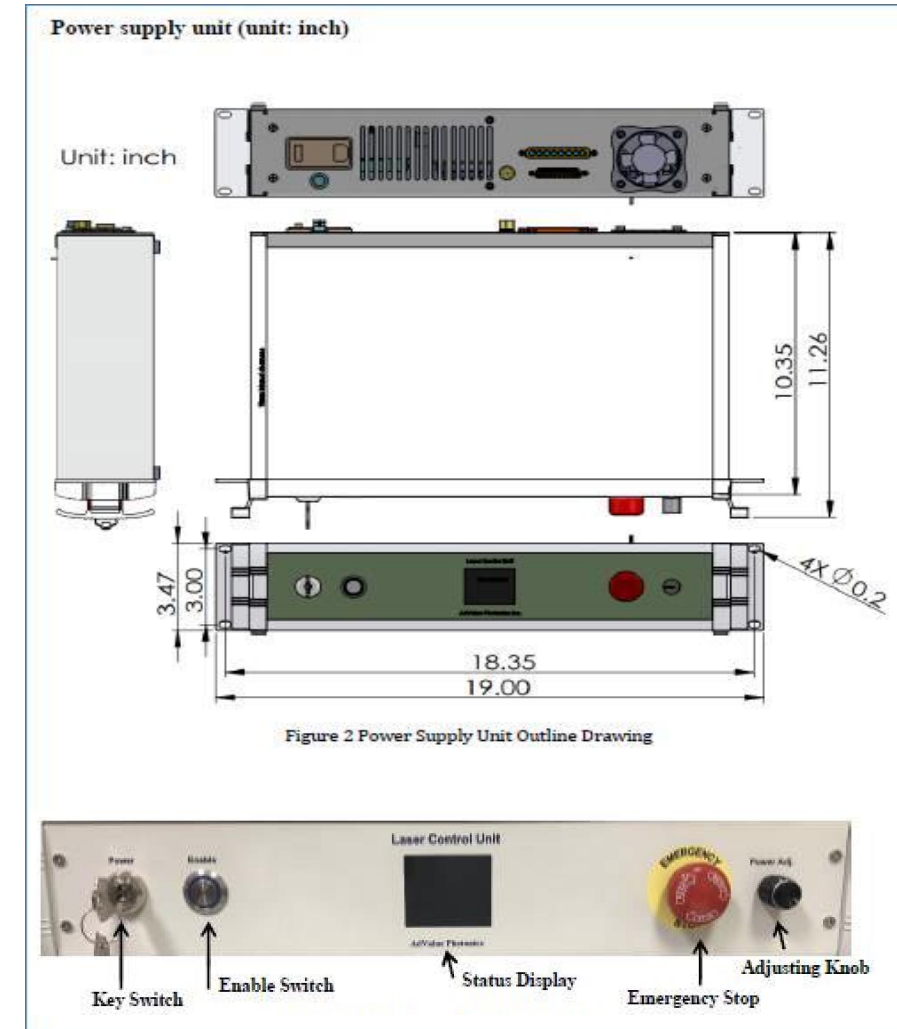
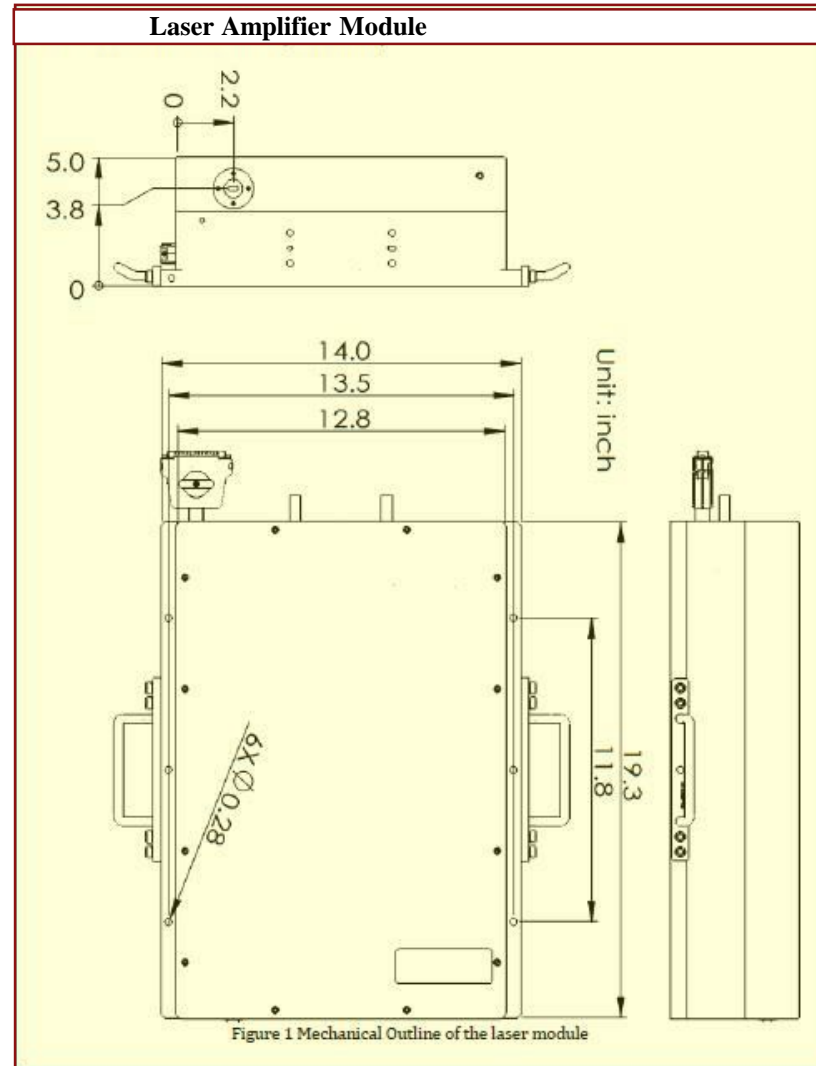


Laser Phase Stability measurement (Vertical deg/100, Horizontal- hrs).
Total phase drift < 1 deg over 8.5 hrs



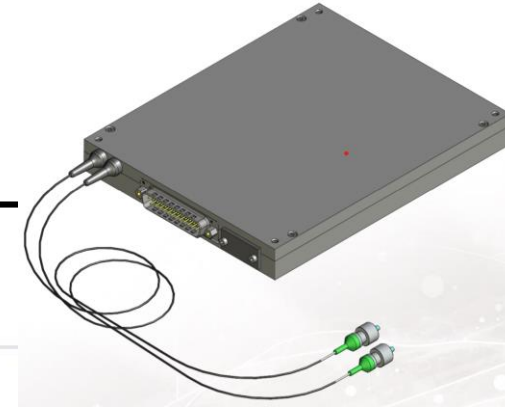
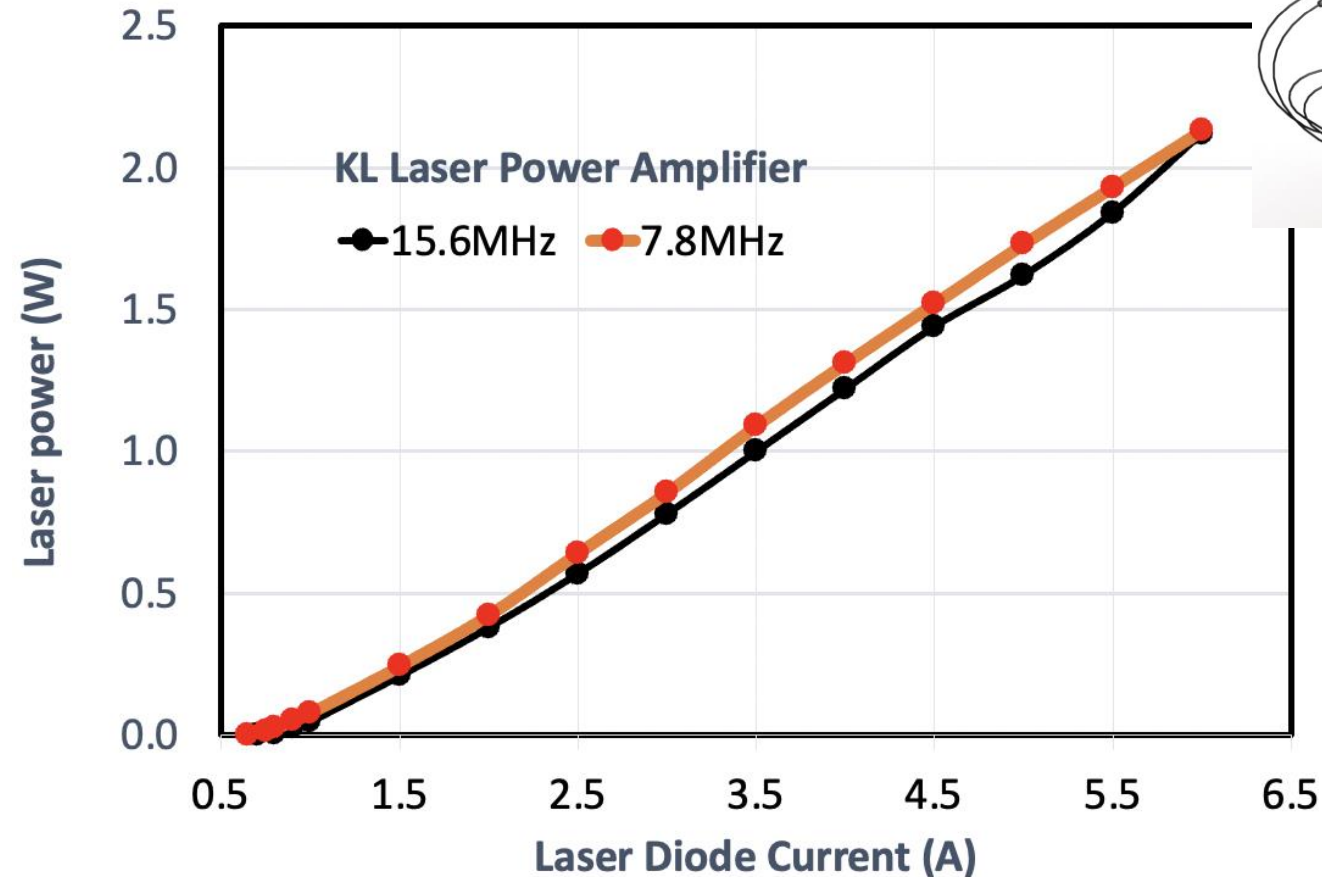
Amplifier: Proposed Earlier -1.5um High Pulse Energy Fiber Laser Amplifier

- For input signal (customer seed laser pulses):
wavelength 1.5 μm ,
average power >1 mW
Pulse length 30~50 ps
- Average power >10 W
Pulse energy >1 μJ
Pulse rate >1 MHz
Linear polarization
Output beam: free-space, collimated
- Package: [amplifier module + control unit], turn-key system



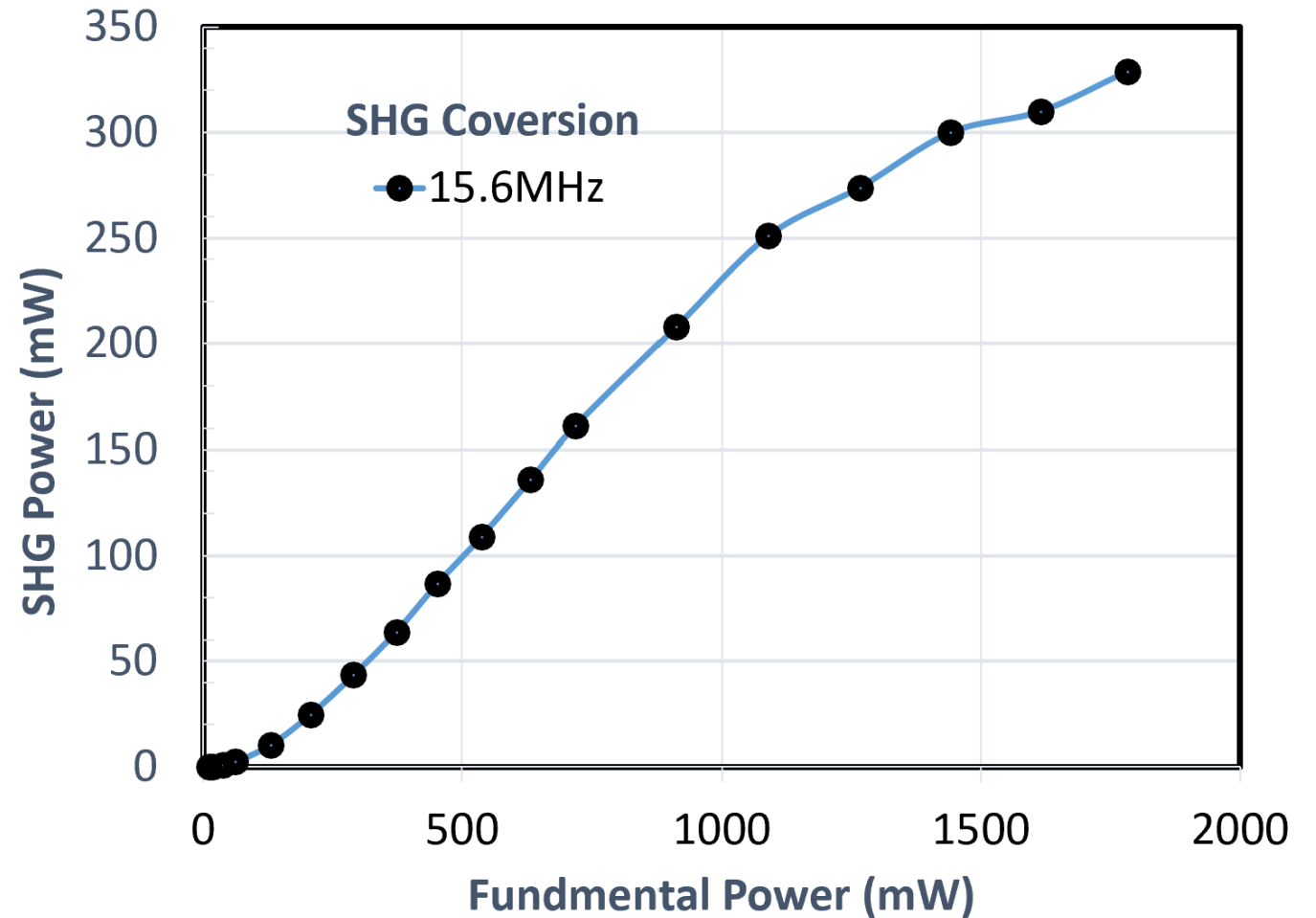
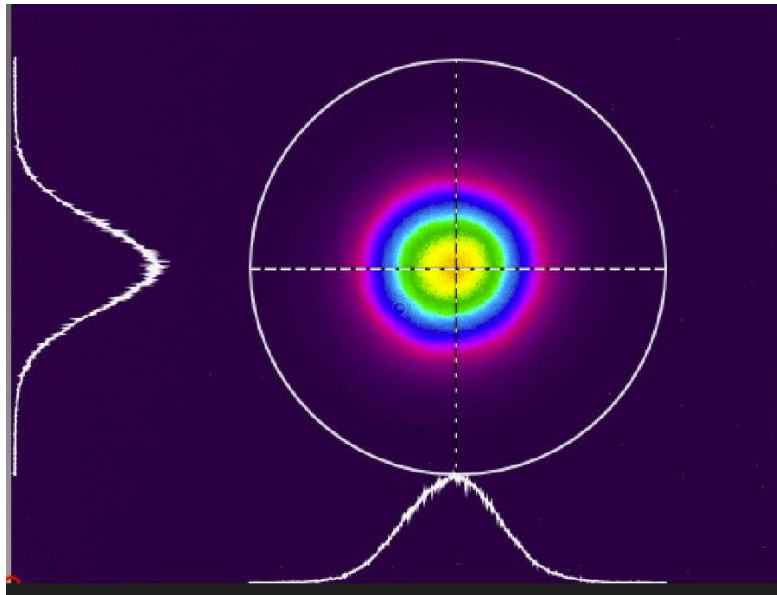
A New 1.5um High Pulse Energy Fiber Laser Amplifier

- Pulse length 30~50 ps
- Output beam: 1 mm (Gaussian) collimated
- Average power >2 W
- Pulse rate: **15.6 or 7.8MHz**
- Pulse energy @ 1.5um
 - > 60nJ @15.6MHz,
 - > 120nJ @7.8MHz
- 0.78um (projected)
 - > 6 nJ @15.6MHz,
 - > 20 nJ @7.8MHz



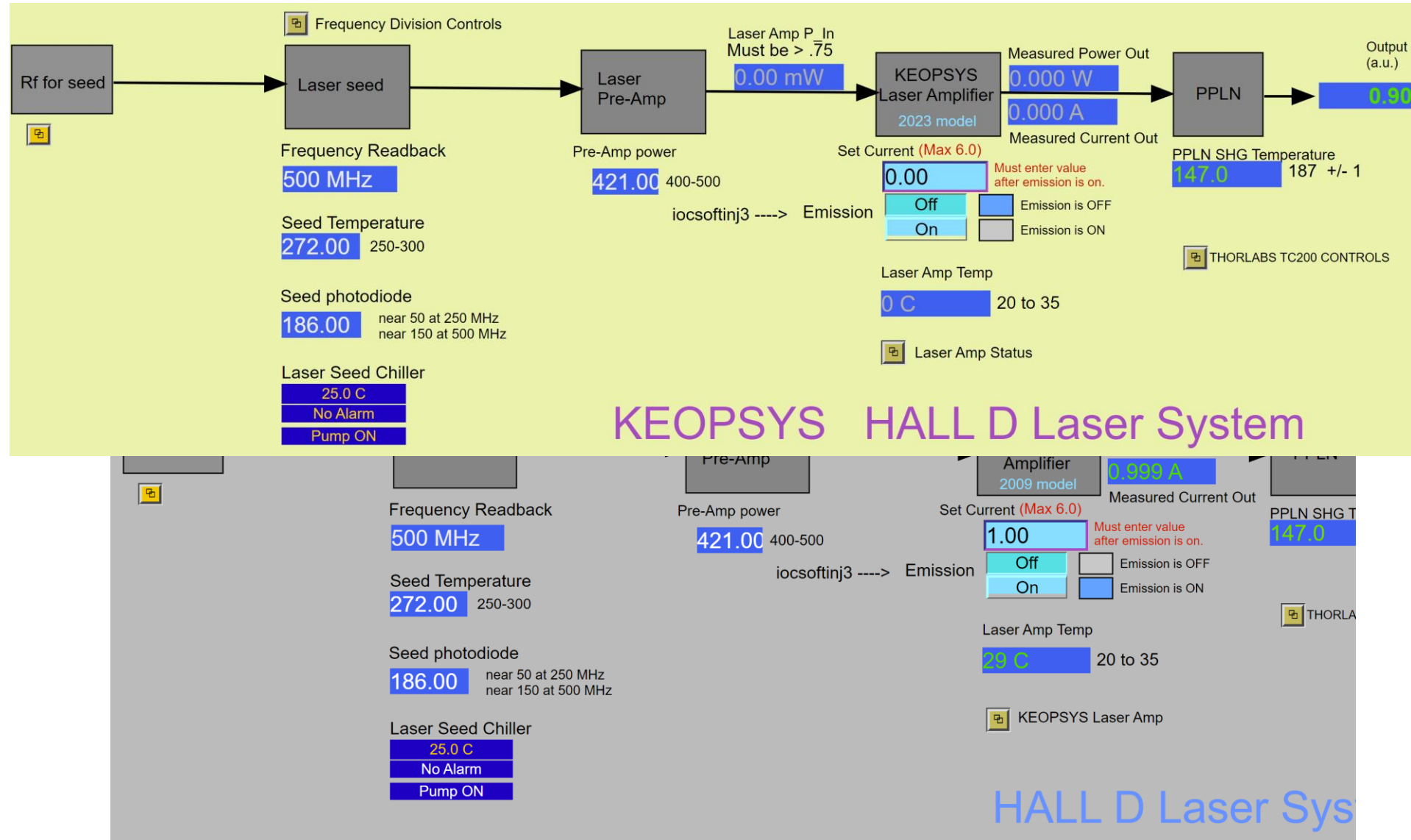
Generating 0.78um Beam

- **>300mW** SHG at 15.6MHz
- Pulse energy **~20 nJ**
- Enough for KLong beam



EPICS Control & Attempt To Install New Laser Into CBAF

- EPICS control software developed & tested
- Attempted to install the laser system during a recent MD
- Backed out due to component issues
- Will try on the next opportunity



Summary & Prospect

- Built a new seed laser
- Implemented a temporary RF frequency division system
 - Phase stability tested at both 15.59 and 7.8 MHz
- Tested new amplifier and SHG, produced >300 mW 780nm beam
- Developed EPICS control
- Assembled & attempted unsuccessfully to install due to optical damage, will try again on next opportunity
- Expected to be fully ready for beam test within a few weeks
- **What are still needed?**
 - A better/robust Laser RF system similar to existing 4 Lasers
 - Software Improvement