NOVEL FIBER LASER SYSTEM FOR PHOTO CATHODE RF GUN

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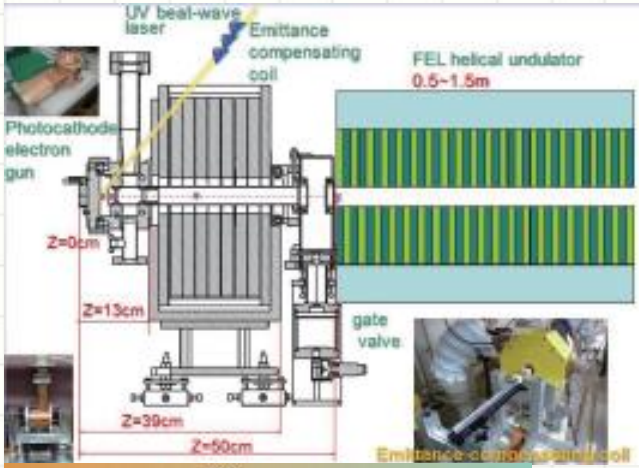
Outline

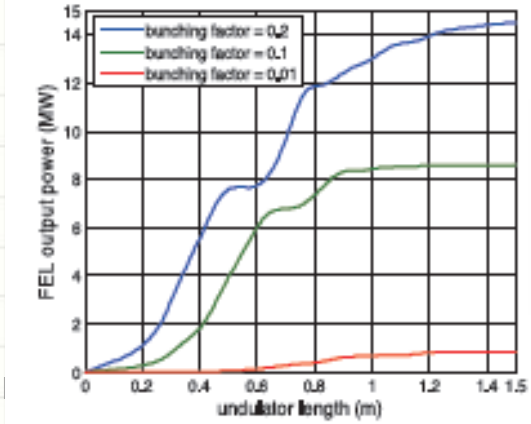
- Compact pre-bunched FEL schemes
- Multi-micro-bunch, concept
- RF Gun laser system technologies
- Multi-micro-bunch, concept
- RF gun fiber laser system
  - Timing system
  - Oscillator
  - Pulse picker
  - Pre.Amp
  - Main Amplifier
  - FHG
  - Pulse splitter (“Laser Buncher”)
- Summary

Compact pre-bunched FEL schemes

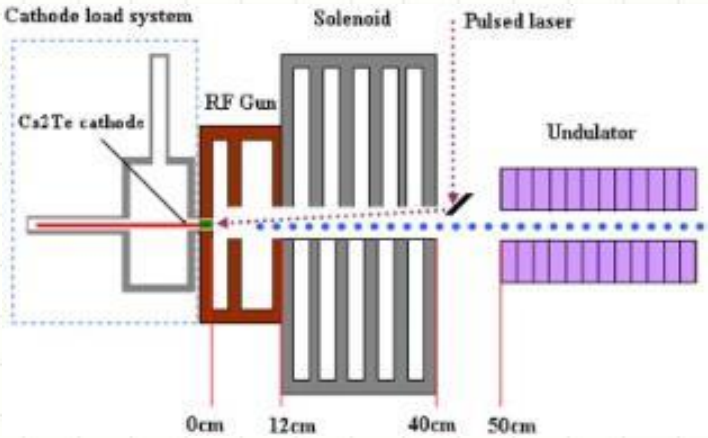
Prof. Y.-C. Huang, National Tsinghua University, Hsinchu, Taiwan



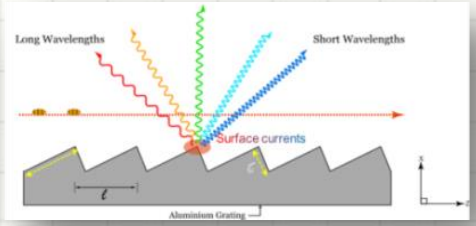
peak gradient	Charges	rms beam radius (mm)	σ_w	σ_μ	micro-pulse rate	Bunching factor @ 2 THz
120 MV/m	1 nC	0.6	4.25 ps	50 fs	2 THz	0.85

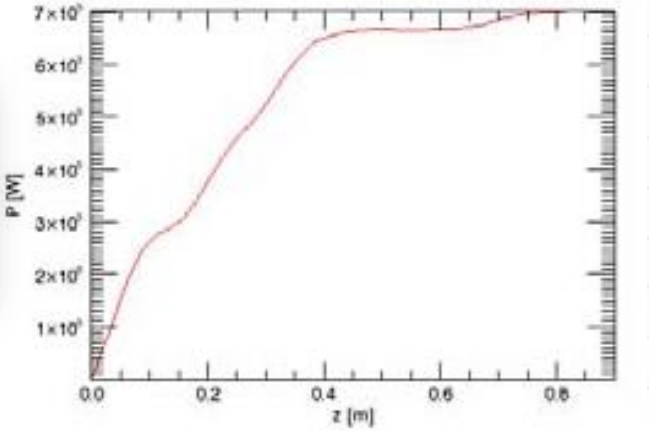


Shengguang Liu, Yen-Chieh Huang, NIM A 637 (2011) S172–S176

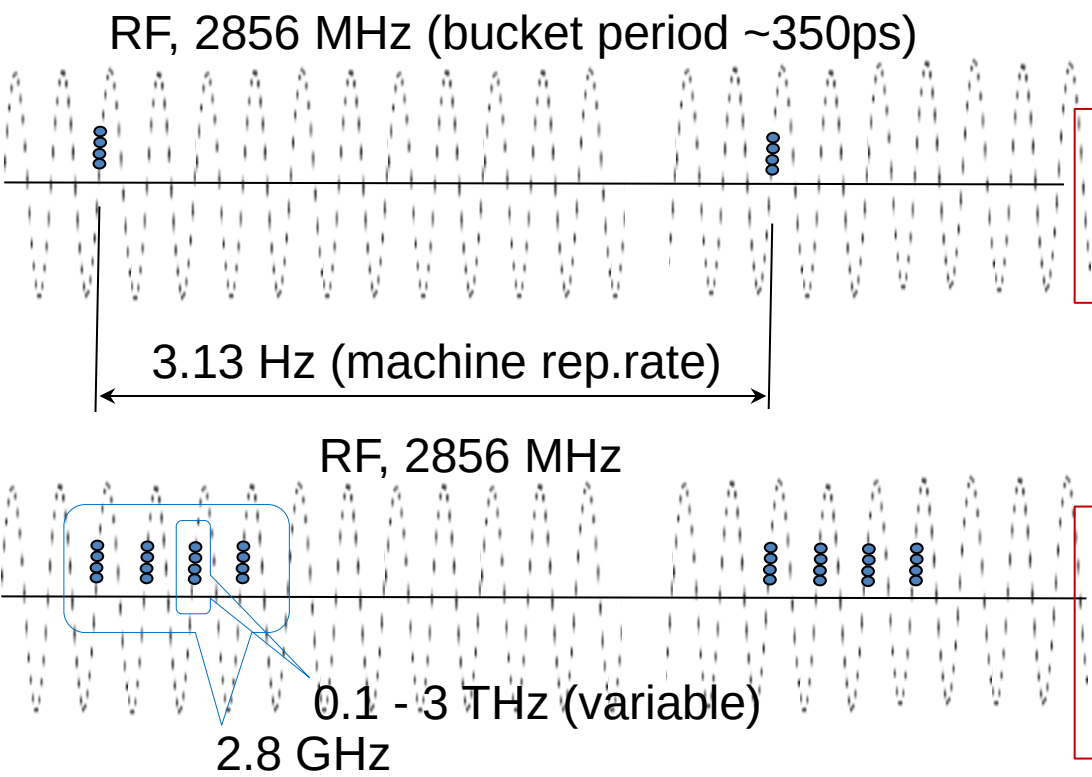


@2THz (150 um), time spacing between laser pulses is 500fs. 16-pulse train of 50fs. Pulse train charge more than200pC, photocathode Q.E. 1%. Peak power at megawatt(MW) level, 0.1 mJ





Multi-micro-bunch, concept



4 micro-bunches
1 multi-bunch (1 RF bucket)

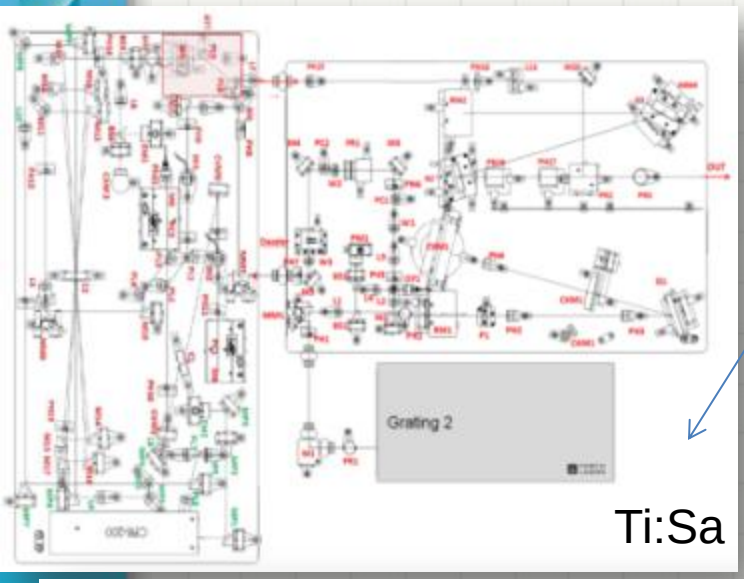
- Number of filled RF buckets depends only on FH laser energy budget
- Non-sequential RF bucket filling is possible

4 micro-bunches
4 multi-bunch (4 RF buckets)

- DAQ sees this micro-train as a single event (<u>no trigger modification is required</u>)
- Micro-bunch spacing can be changed simultaneously in all buckets

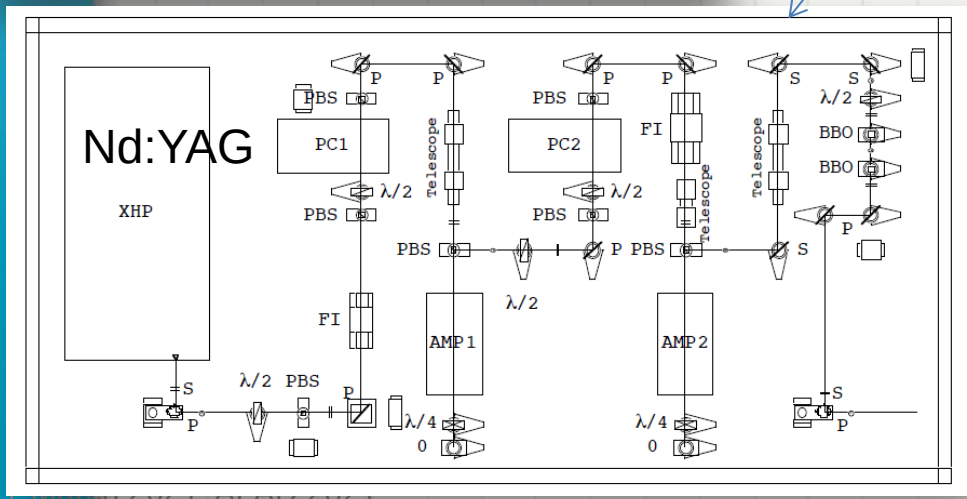
RF Gun laser system technologies

- Solid-state-based technology



Hz rep.rate
fs pulse
High Energy
Complexity

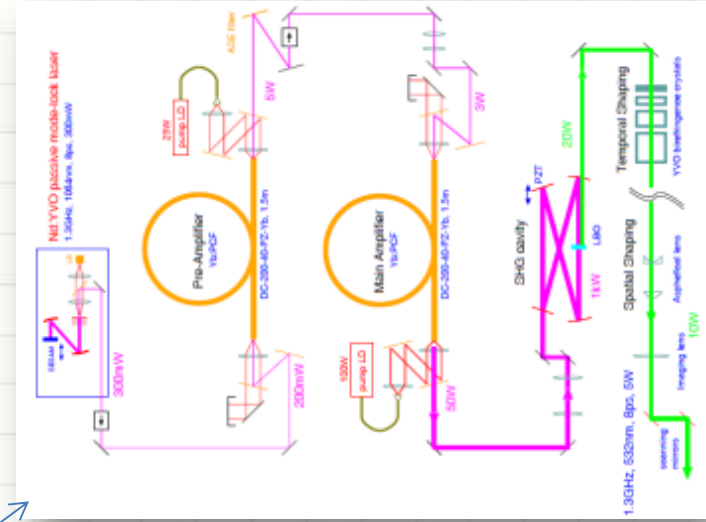
Hz rep.rate
ps pulse
High Energy
Simplisity



MHz rep.rate
~100 fs pulse
Low Energy
Simplisity

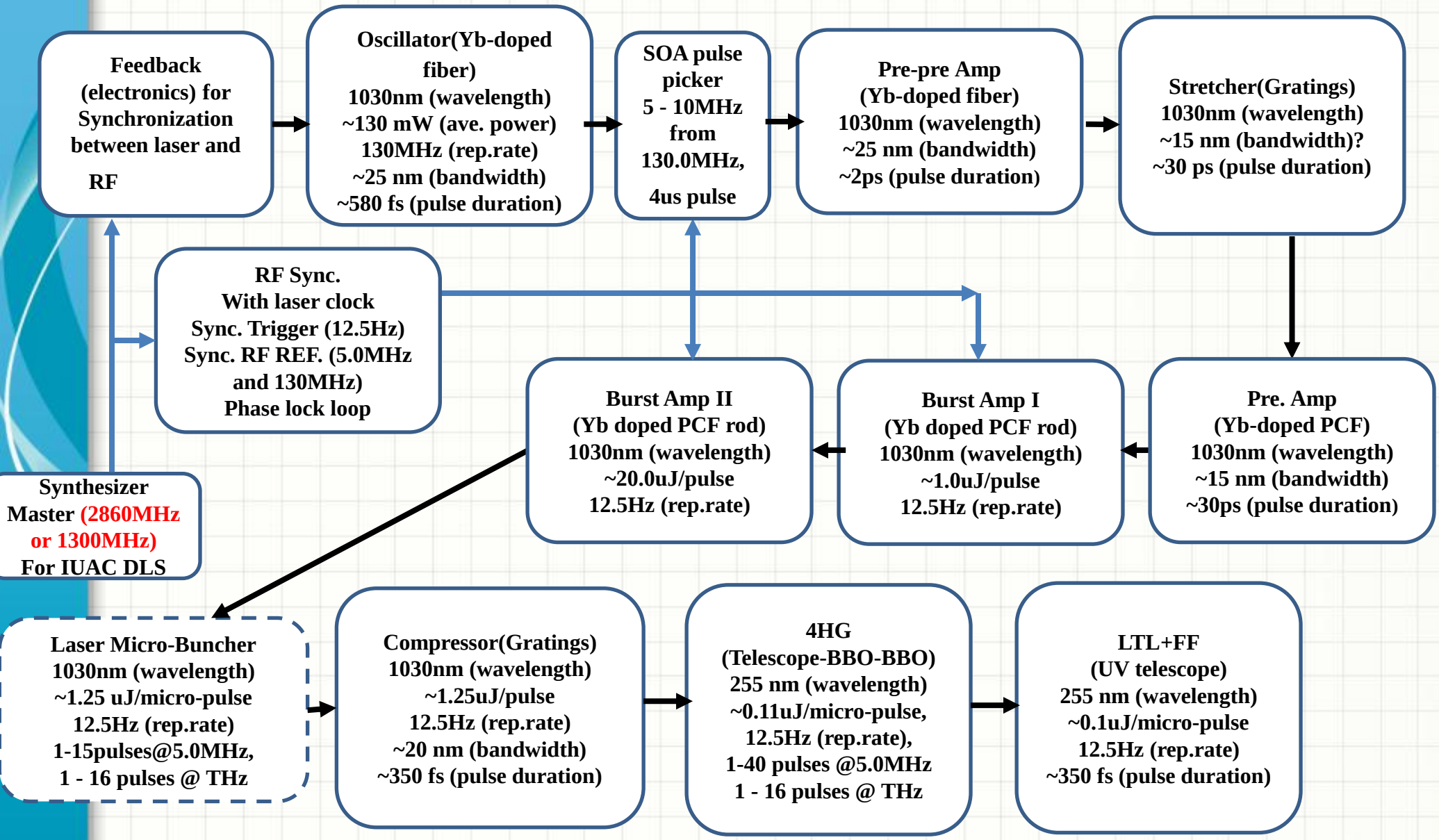
- Fiber-based technology

Yb-dopped fiber for example

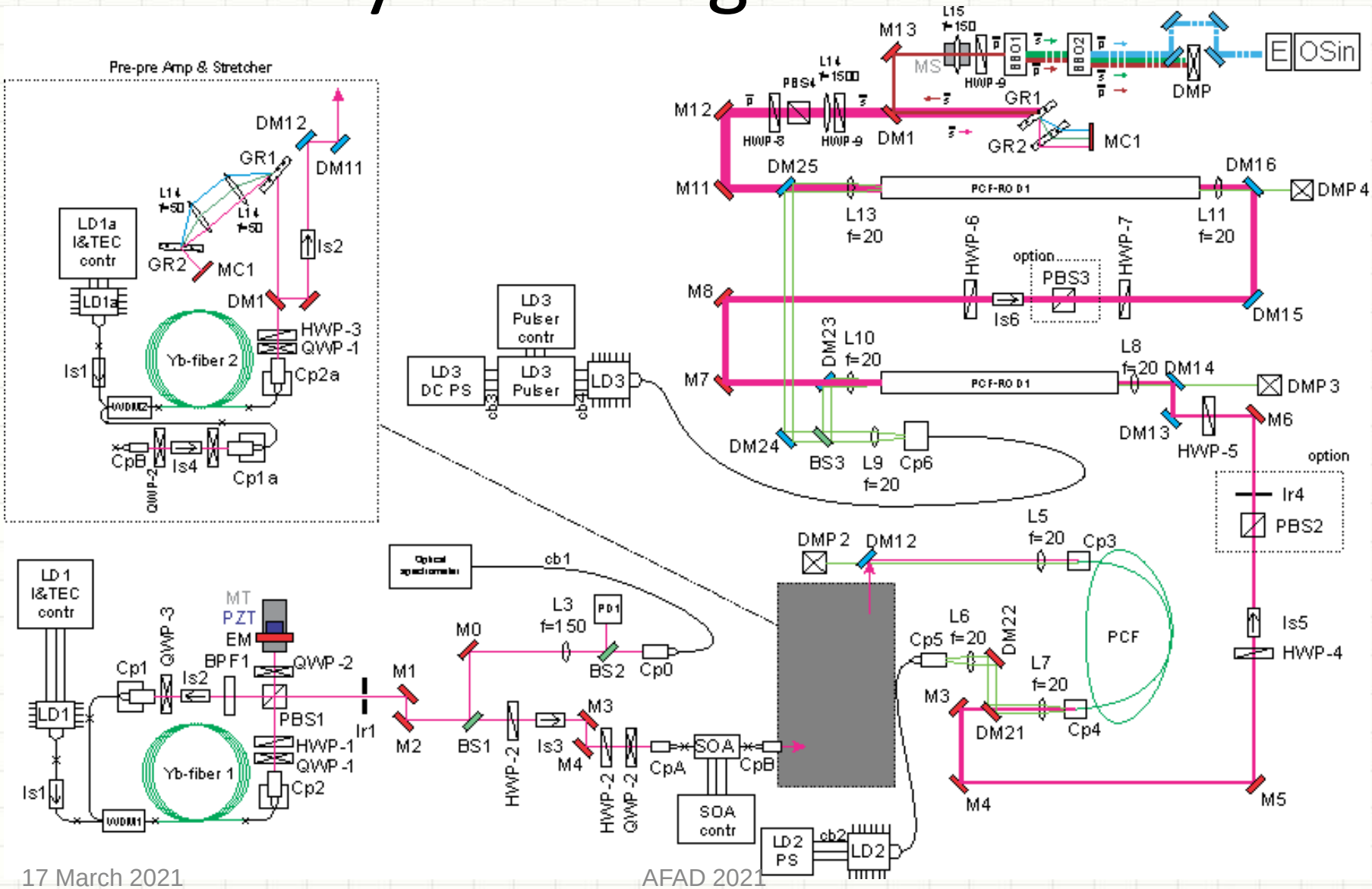


courtesy Y. Honda (KEK)

A. Chong, W.H. Renninger, F. W. Wise, Opt. Lett. 33 (2008) 2638:
Numerical simulations of Yb-doped fiber lasers indicate that ~30 fs pulses are possible for a realistic design with off-the-shelf components. Experiments are constrained by the available pump power, but ~75 fs pulses are obtained. (just for oscillator !!!)


Feedback (electronics) for Synchronization between laser and RF
Oscillator(Yb-doped fiber)
1030nm (wavelength)
~130 mW (ave. power)
130MHz (rep.rate)
~25 nm (bandwidth)
~580 fs (pulse duration)
SOA pulse picker
5 - 10MHz from 130.0MHz,
4us pulse
Pre-pre Amp
(Yb-doped fiber)
1030nm (wavelength)
~25 nm (bandwidth)
~2ps (pulse duration)
Stretcher(Gratings)
1030nm (wavelength)
~15 nm (bandwidth)?
~30 ps (pulse duration)
RF Sync.
With laser clock
Sync. Trigger (12.5Hz)
Sync. RF REF. (5.0MHz and 130MHz)
Phase lock loop
Burst Amp II
(Yb doped PCF rod)
1030nm (wavelength)
~20.0uJ/pulse
12.5Hz (rep.rate)
Burst Amp I
(Yb doped PCF rod)
1030nm (wavelength)
~1.0uJ/pulse
12.5Hz (rep.rate)
Pre. Amp
(Yb-doped PCF)
1030nm (wavelength)
~15 nm (bandwidth)
~30ps (pulse duration)
Synthesizer
Master (2860MHz or 1300MHz)
For IUAC DLS
Laser Micro-Buncher
1030nm (wavelength)
~1.25 uJ/micro-pulse
12.5Hz (rep.rate)
1-15pulses@5.0MHz,
1 - 16 pulses @ THz
Compressor(Gratings)
1030nm (wavelength)
~1.25uJ/pulse
12.5Hz (rep.rate)
~20 nm (bandwidth)
~350 fs (pulse duration)
4HG
(Telescope-BBO-BBO)
255 nm (wavelength)
~0.11uJ/micro-pulse,
12.5Hz (rep.rate),
1-40 pulses @5.0MHz
1 - 16 pulses @ THz
LTL+FF
(UV telescope)
255 nm (wavelength)
~0.1uJ/micro-pulse
12.5Hz (rep.rate)
~350 fs (pulse duration)

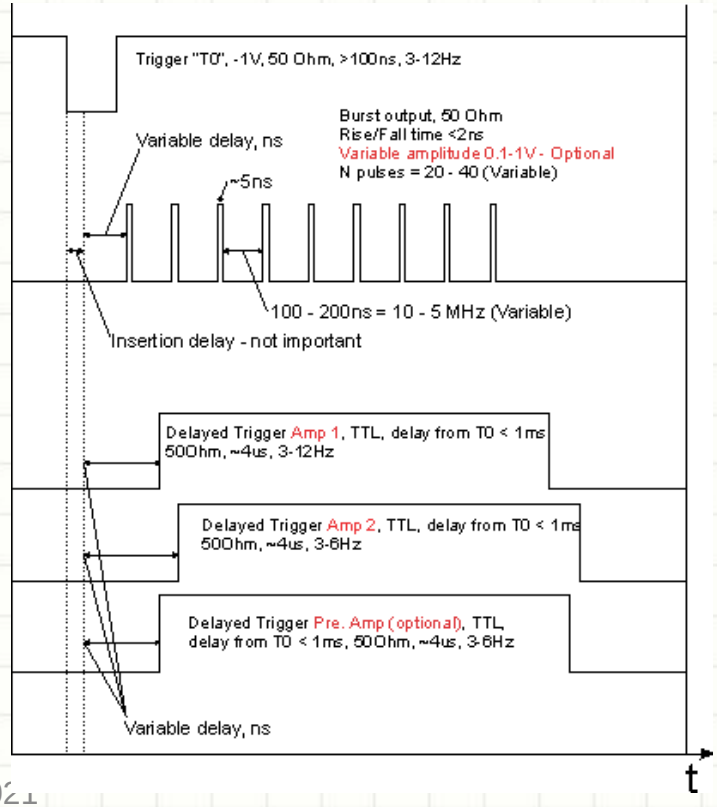
Yb laser system diagram

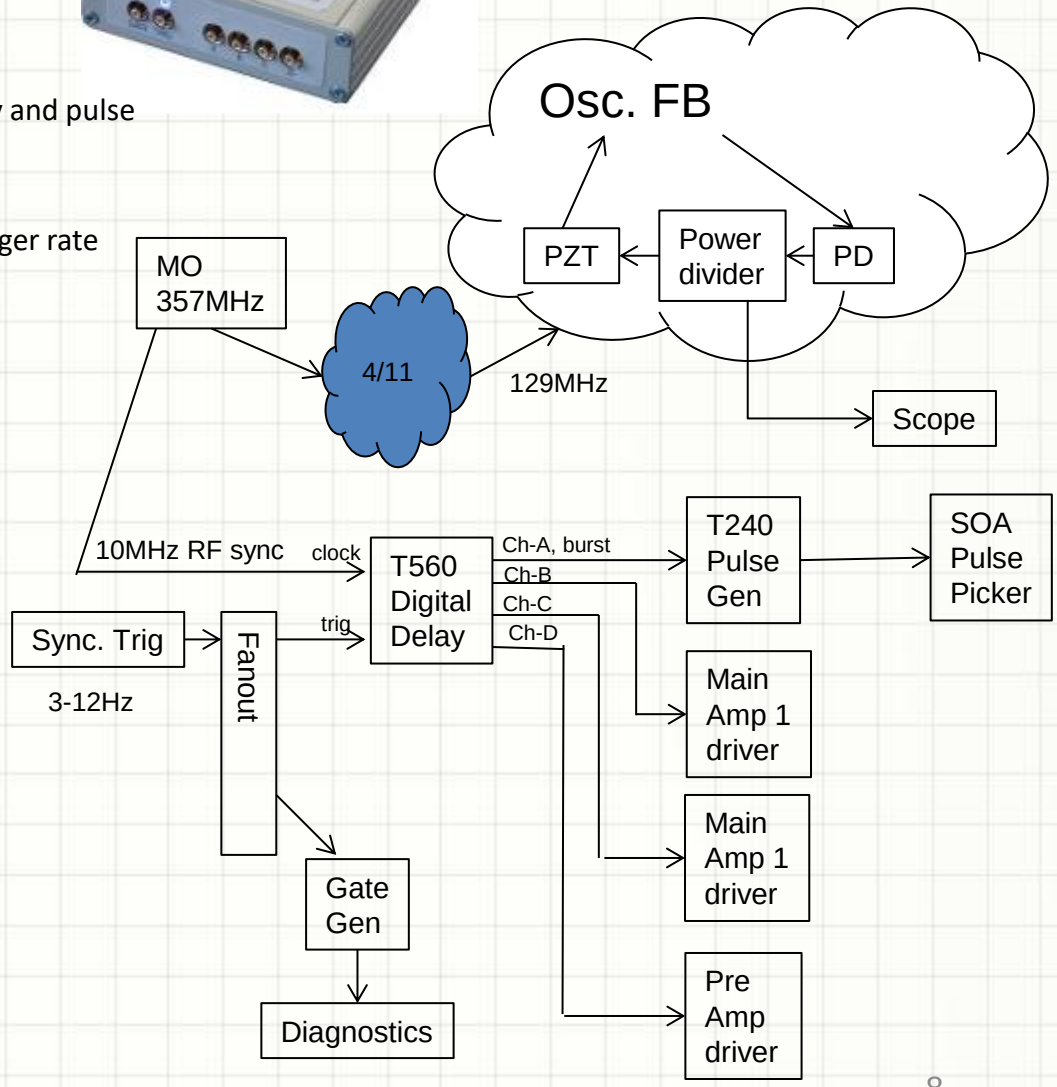


Timing system

Highland Technology

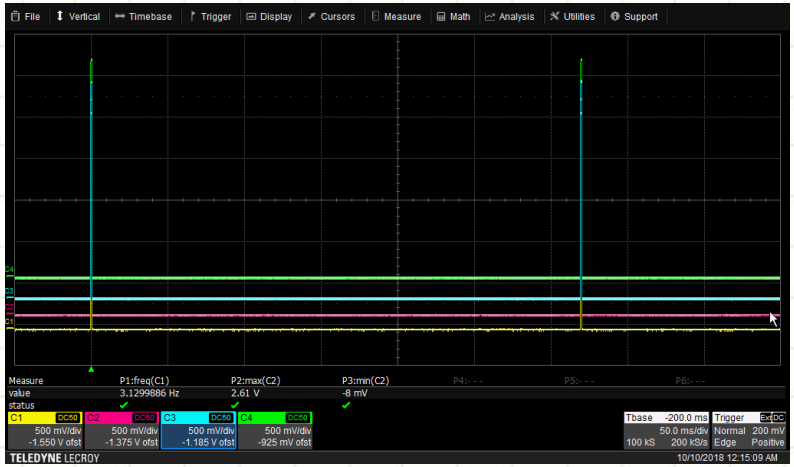
- T560 4-channel compact digital delay and pulse generator.
- Four TTL-level delay outputs, individually programmable for delay and pulse width.
- 10 picosecond delay and width resolution,
- 10 second range 20 nanosecond insertion delay, 16 MHz max trigger rate
- RS-232 serial interface standard; Ethernet optional.





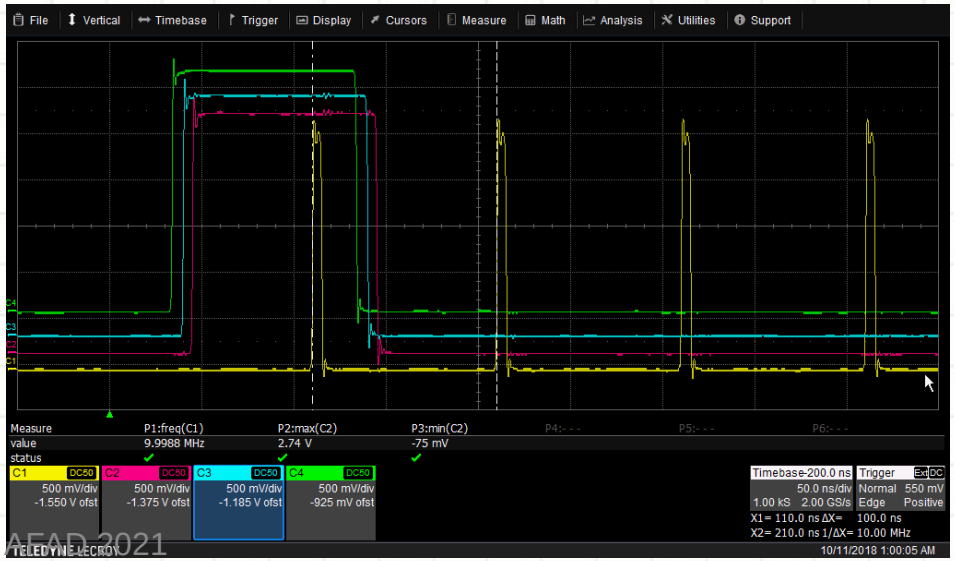
Timing system performance

3 Hz, machine rep. rate

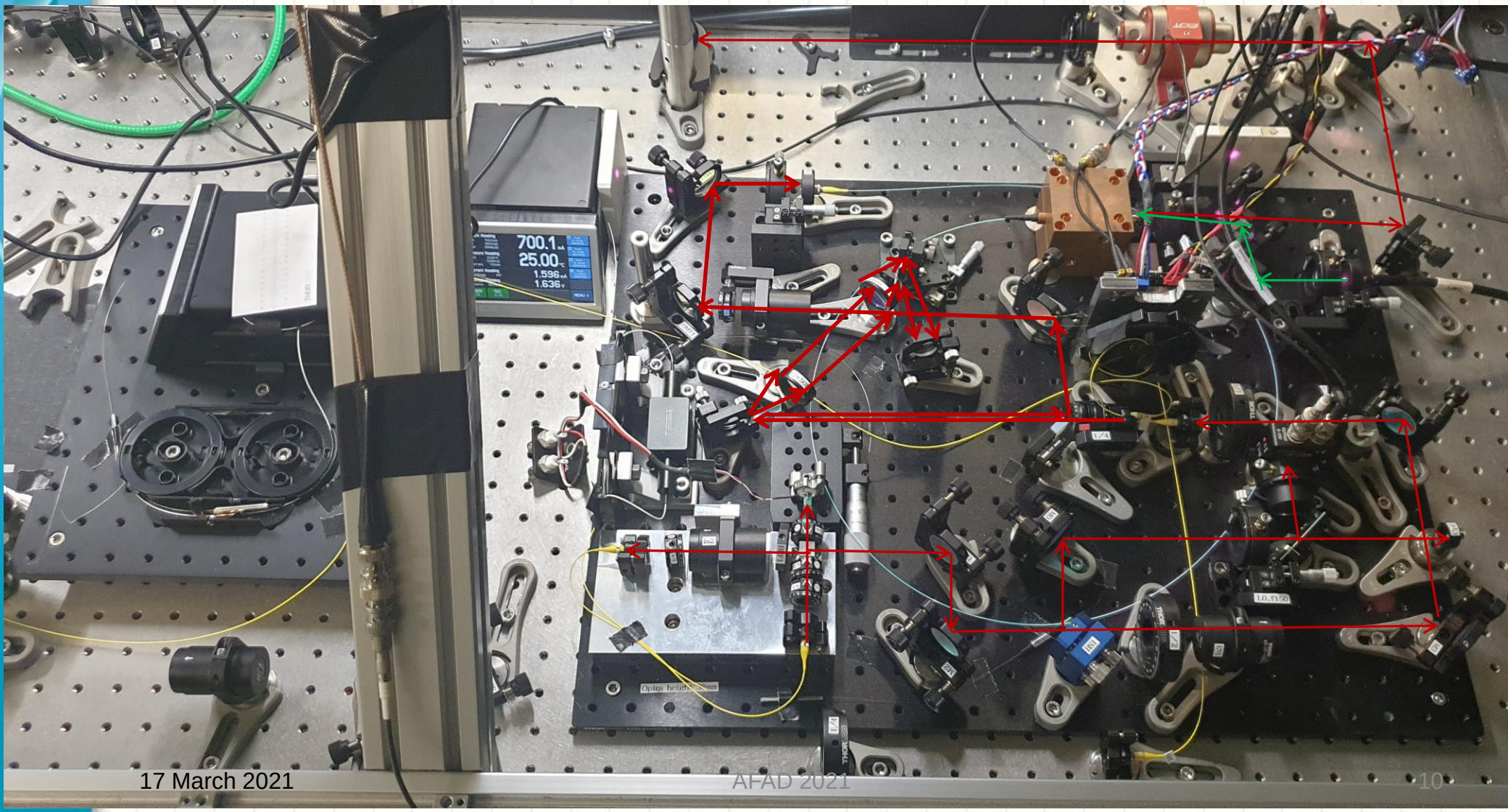


4 us triggers

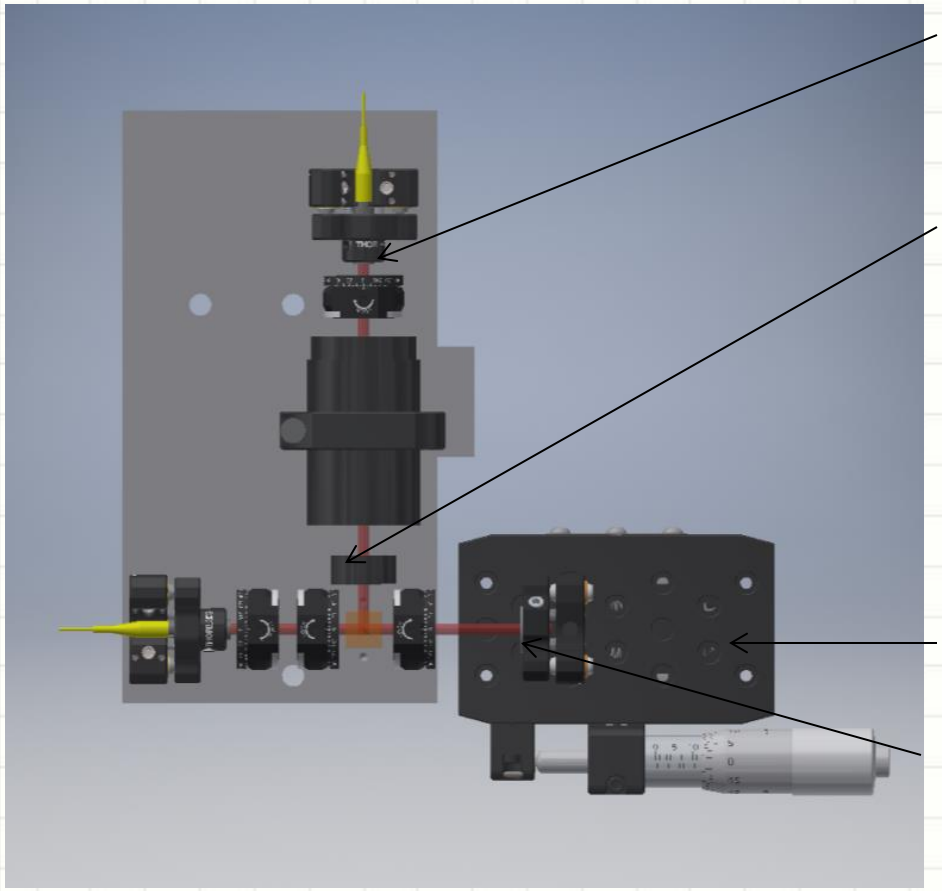
10MHz pulse picking signal,
T560 output



Oscillator, Pulse picker, Pre. Amp



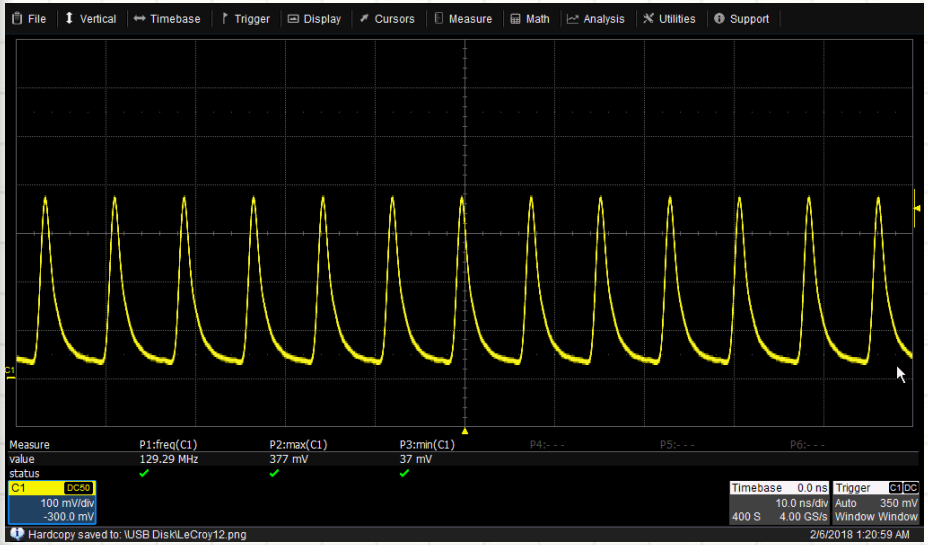
Fiber oscillator

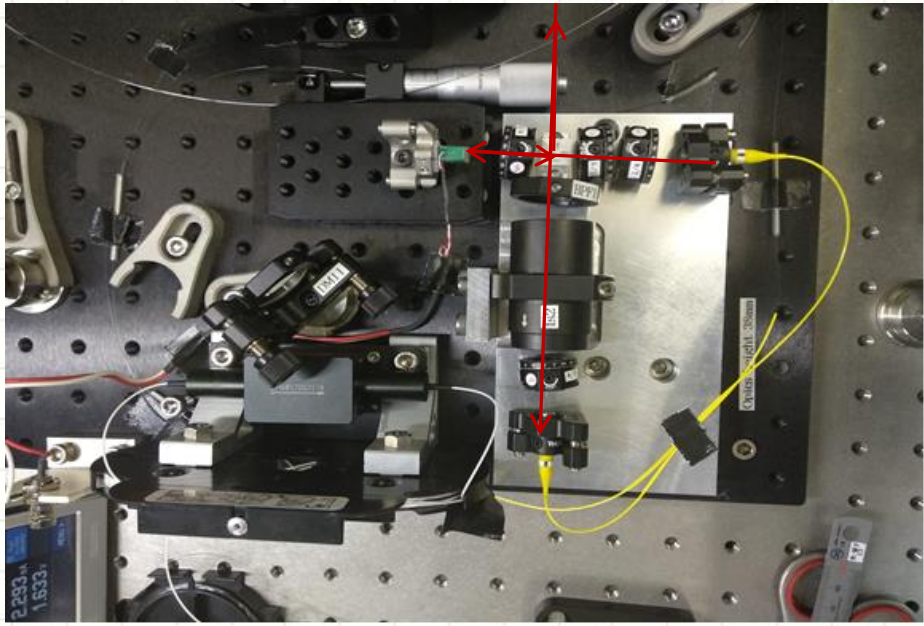


- Common custom baseplate.
- BPF instead of gratings.
- Reduced optical path length.
- Simplified design.
- Linear stage with lock.
- Small mirror on PZT for feedback.

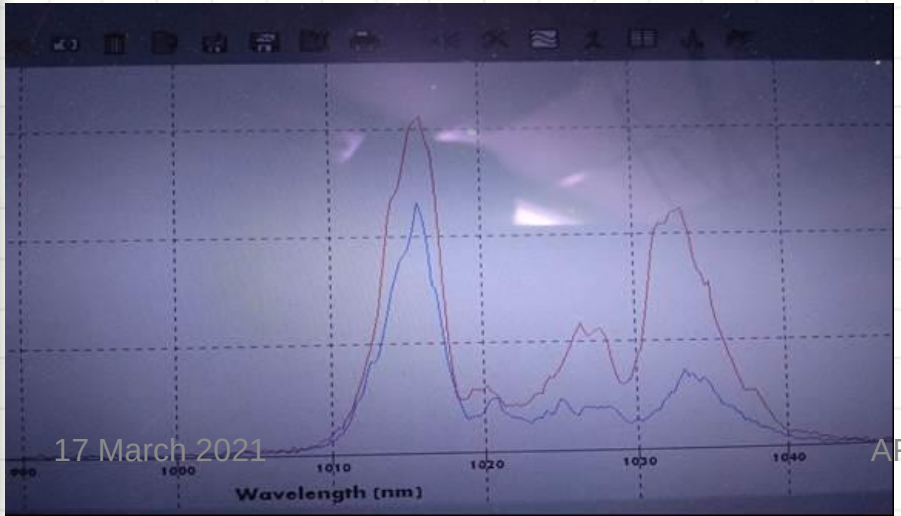
Oscillator performance

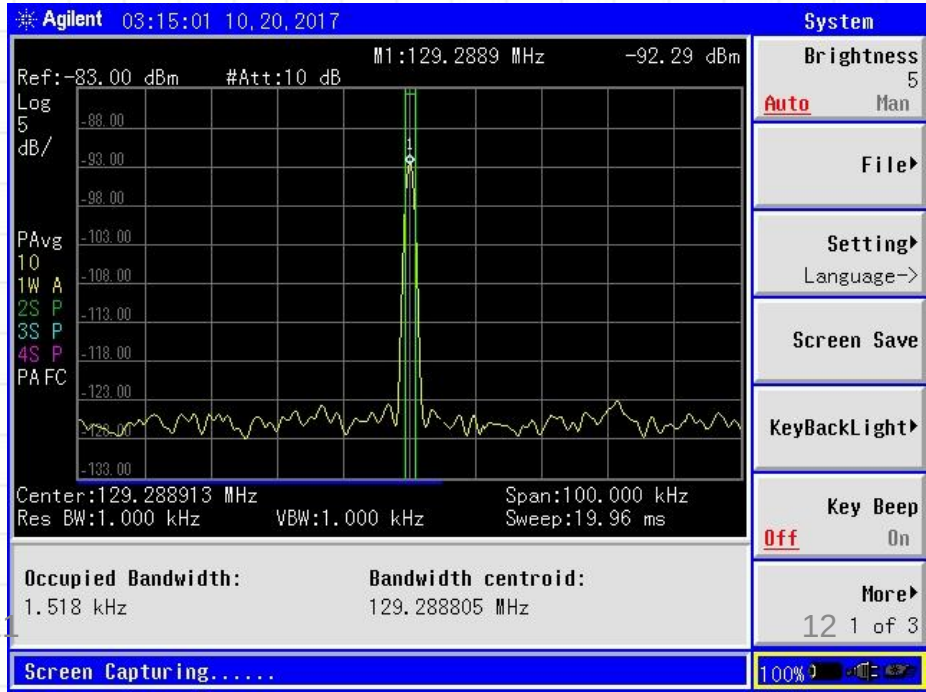
~ 135mW, 0.2% rms stability





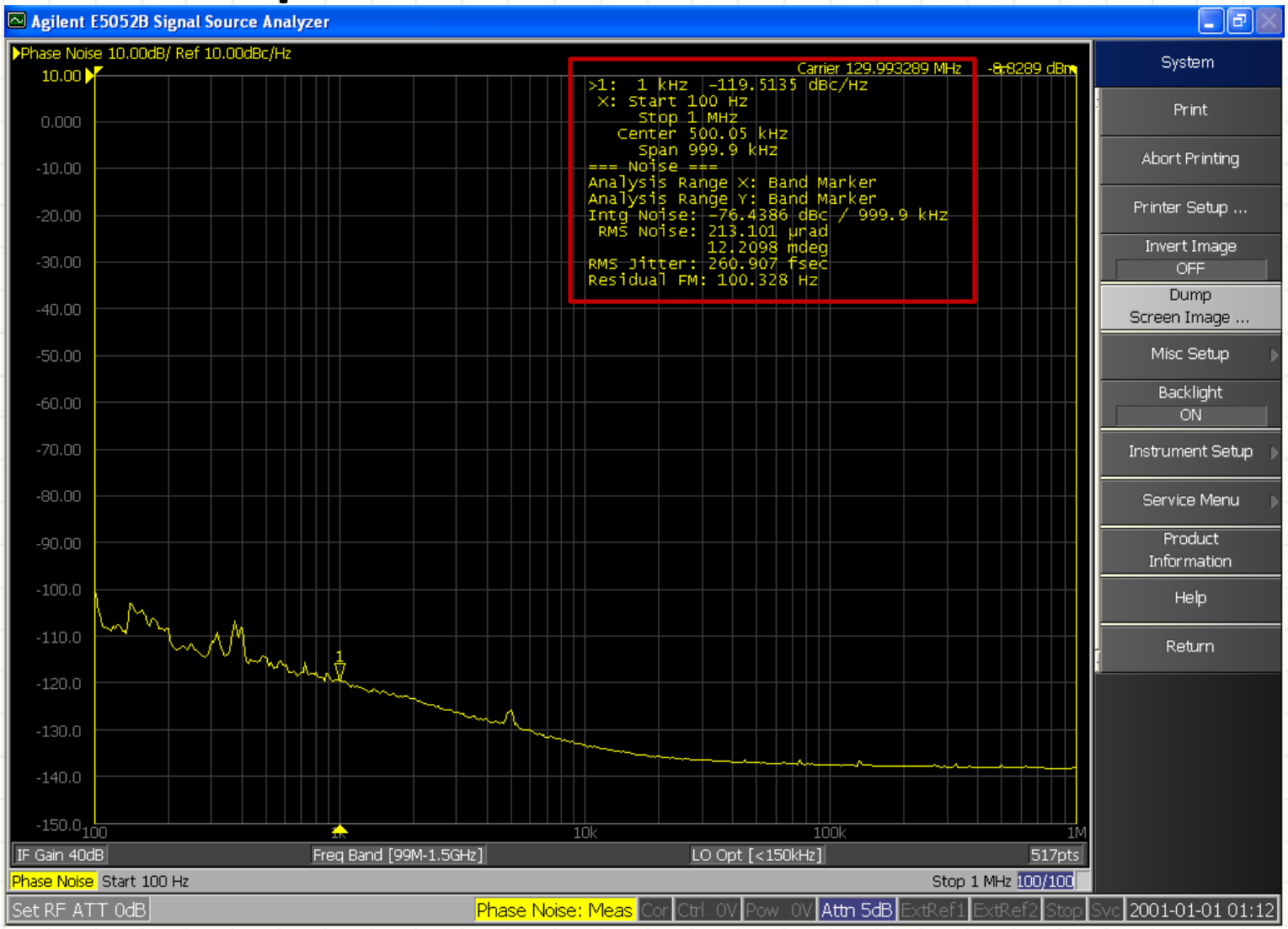
~ 25 nm optical bandwidth



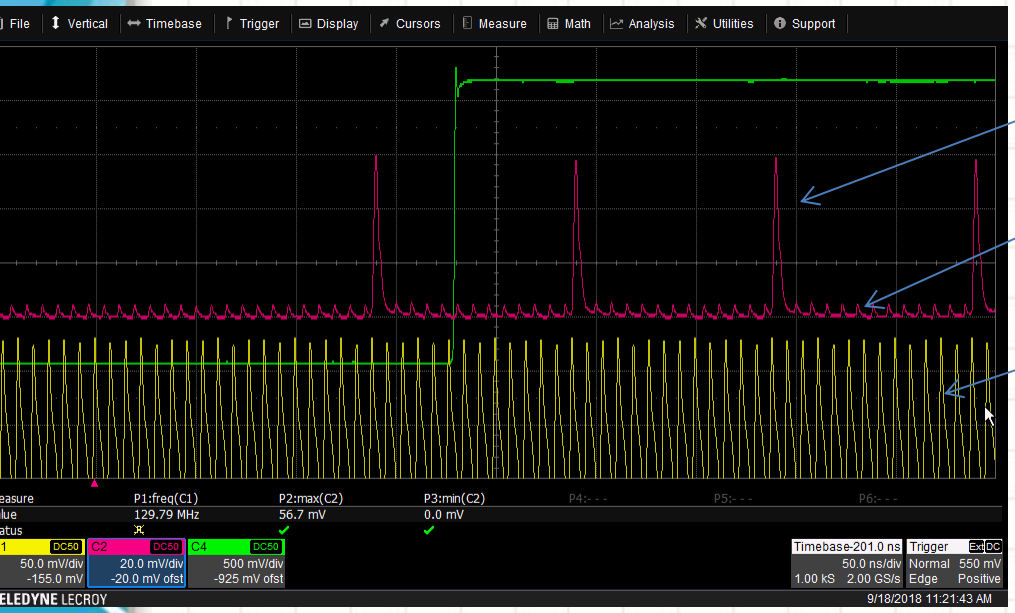


Oscillator performance

FB is off



SOA pulse picker

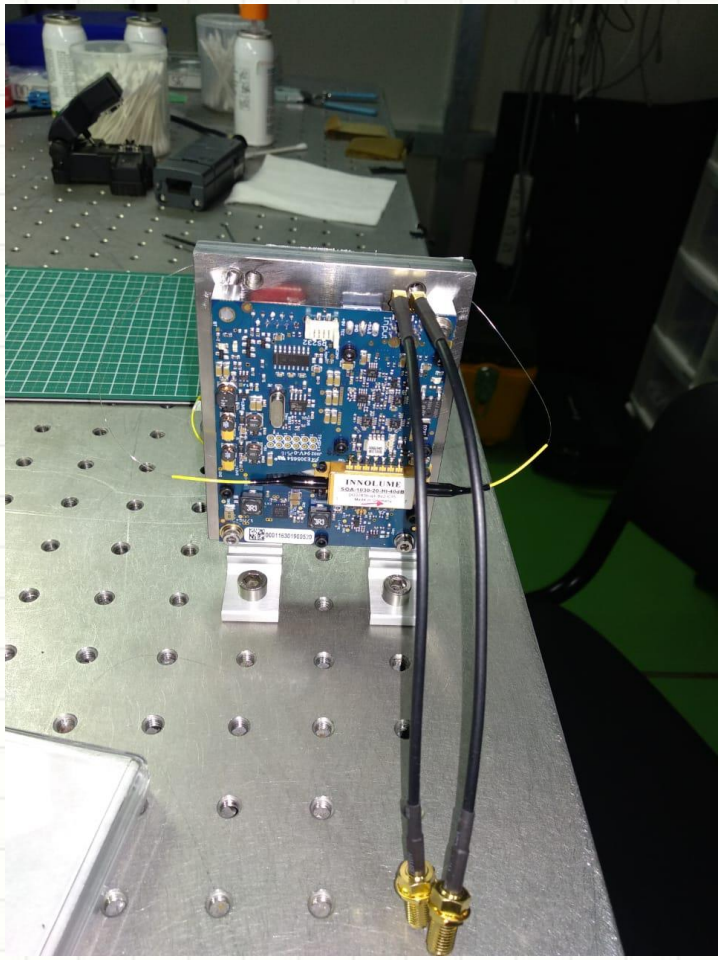


Picked pulses

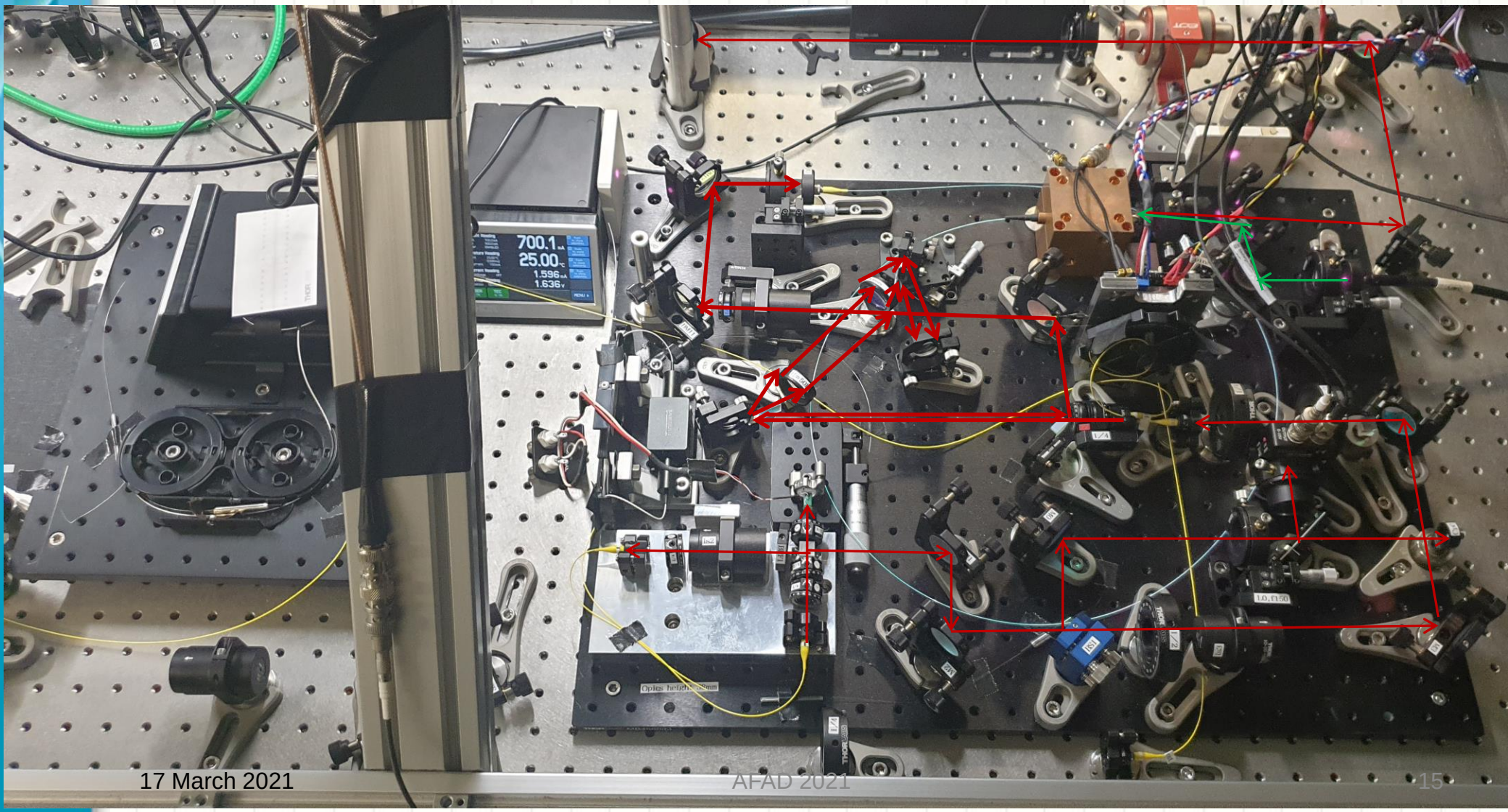
Residual transmission

Oscillator output

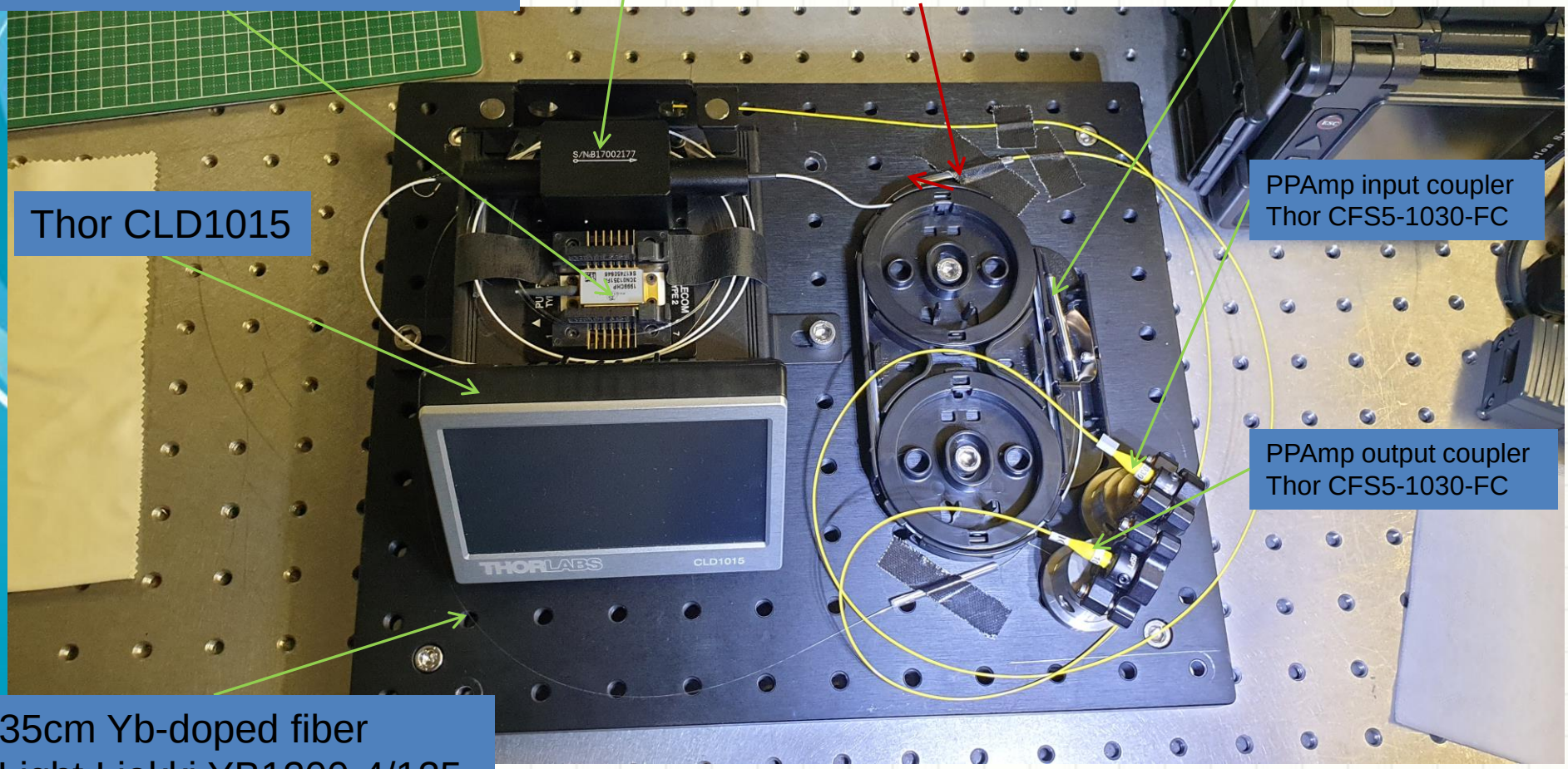
ASE



Oscillator, Pulse picker, Pre. Amp

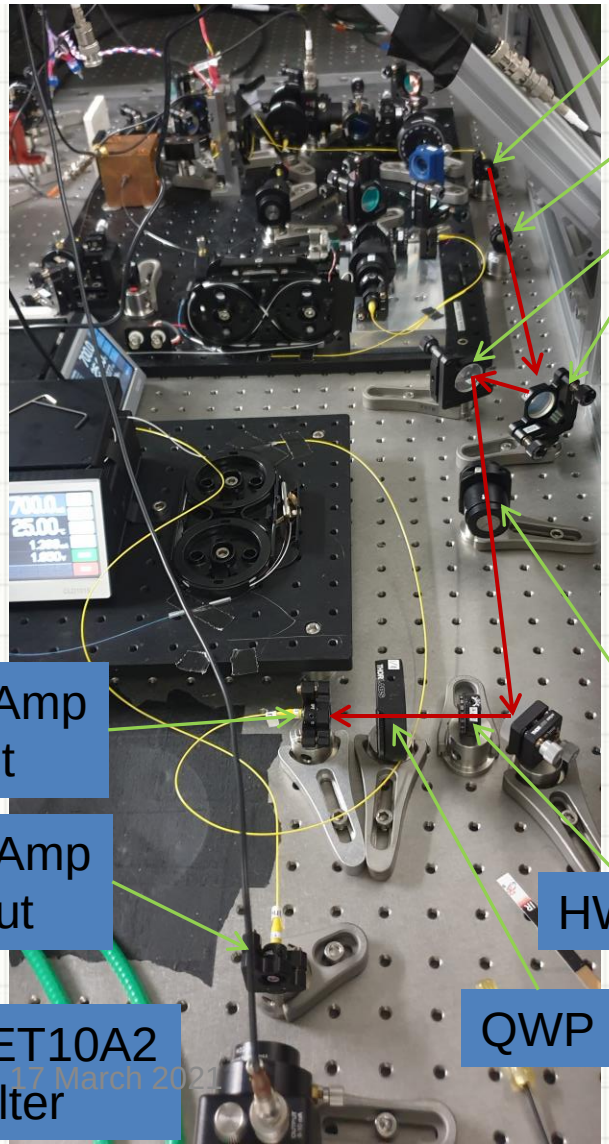


Pre-pre Amplifier



Pre-pre Amplifier

Case 1: No ASE filters after PPAmp



Pulse picker output

QWP

ASE filters

PrePreAmp input

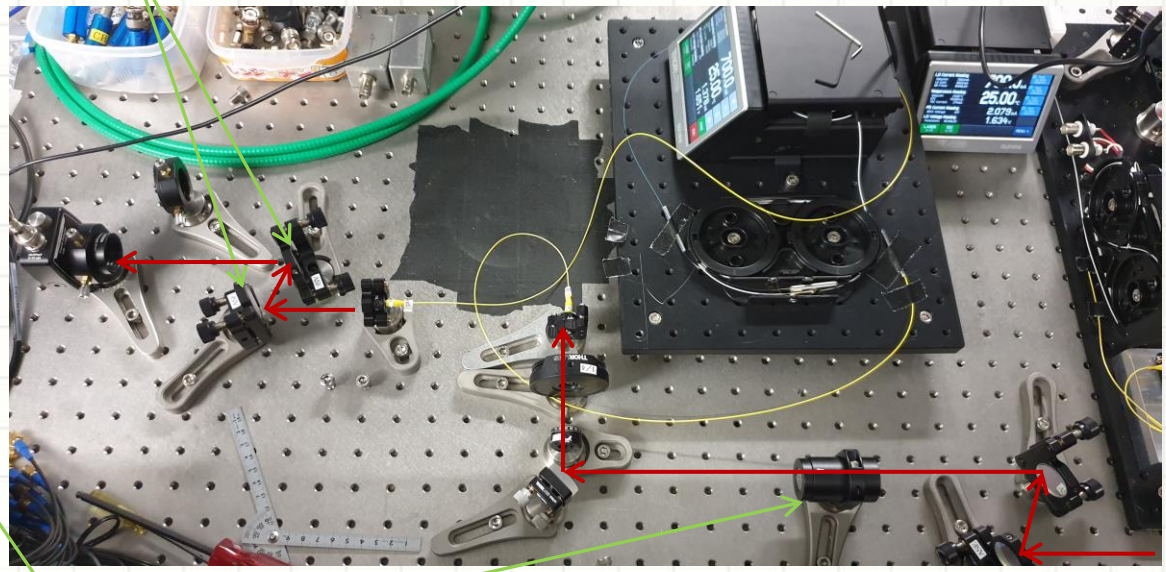
PrePreAmp output

HWP

QWP

Thor DET10A2 ND20 filter

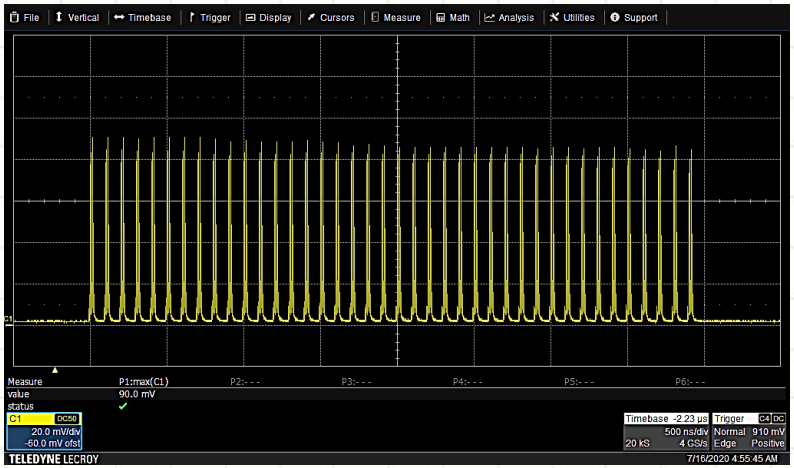
Case 2: 2 ASE filters after PPAmp



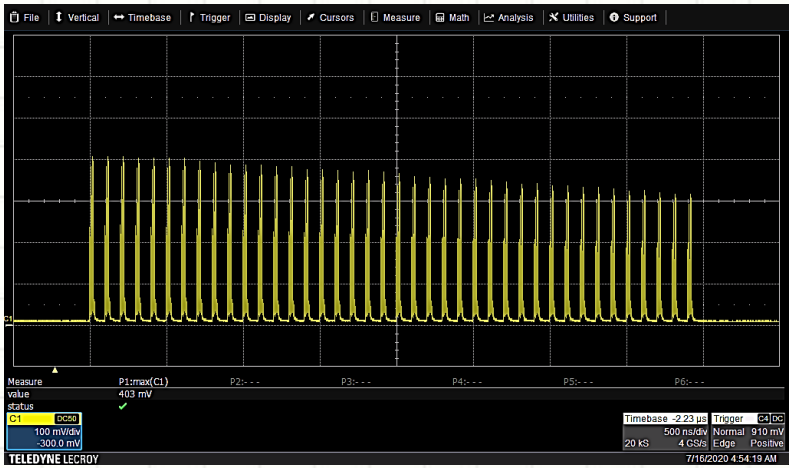
ISO

Pre-pre Amplifier output
Thor DET10A2 ND20 filter (no ASE filters)

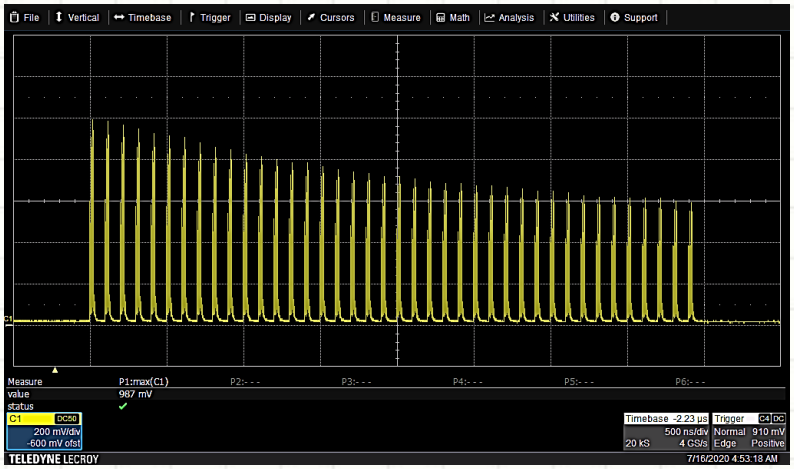
Pumping: 250mA



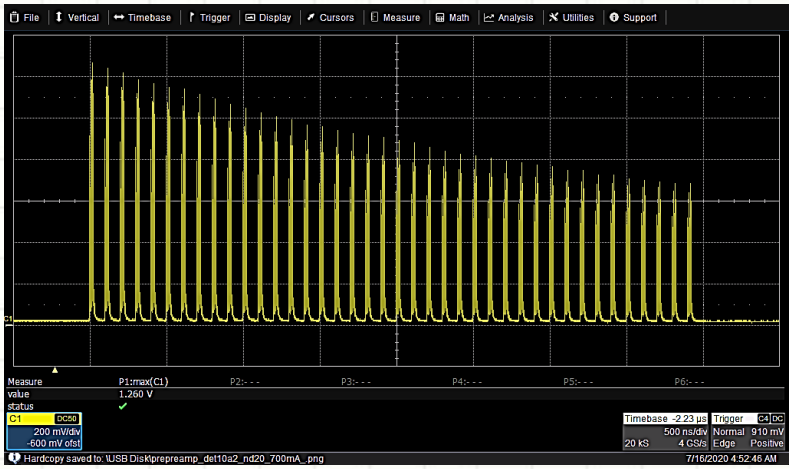
Pumping: 400mA



Pumping: 600mA



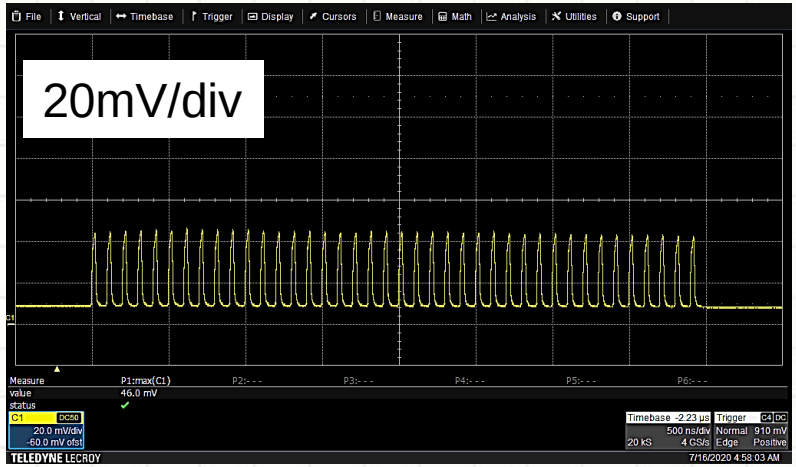
Pumping: 700mA



PPAmp ASE

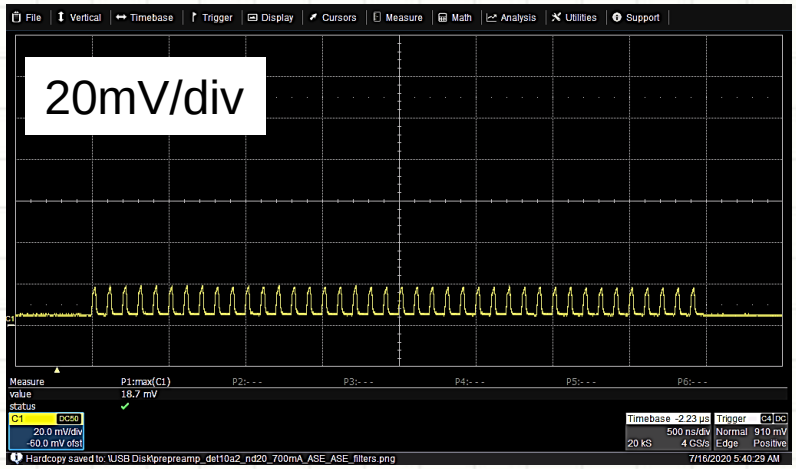
PPAmp DC ASE ~ 8mV
(PPAmp input blocked)

PPAmp DC + Pulsed ASE ~ 46mV
(Pulse Picker input blocked)

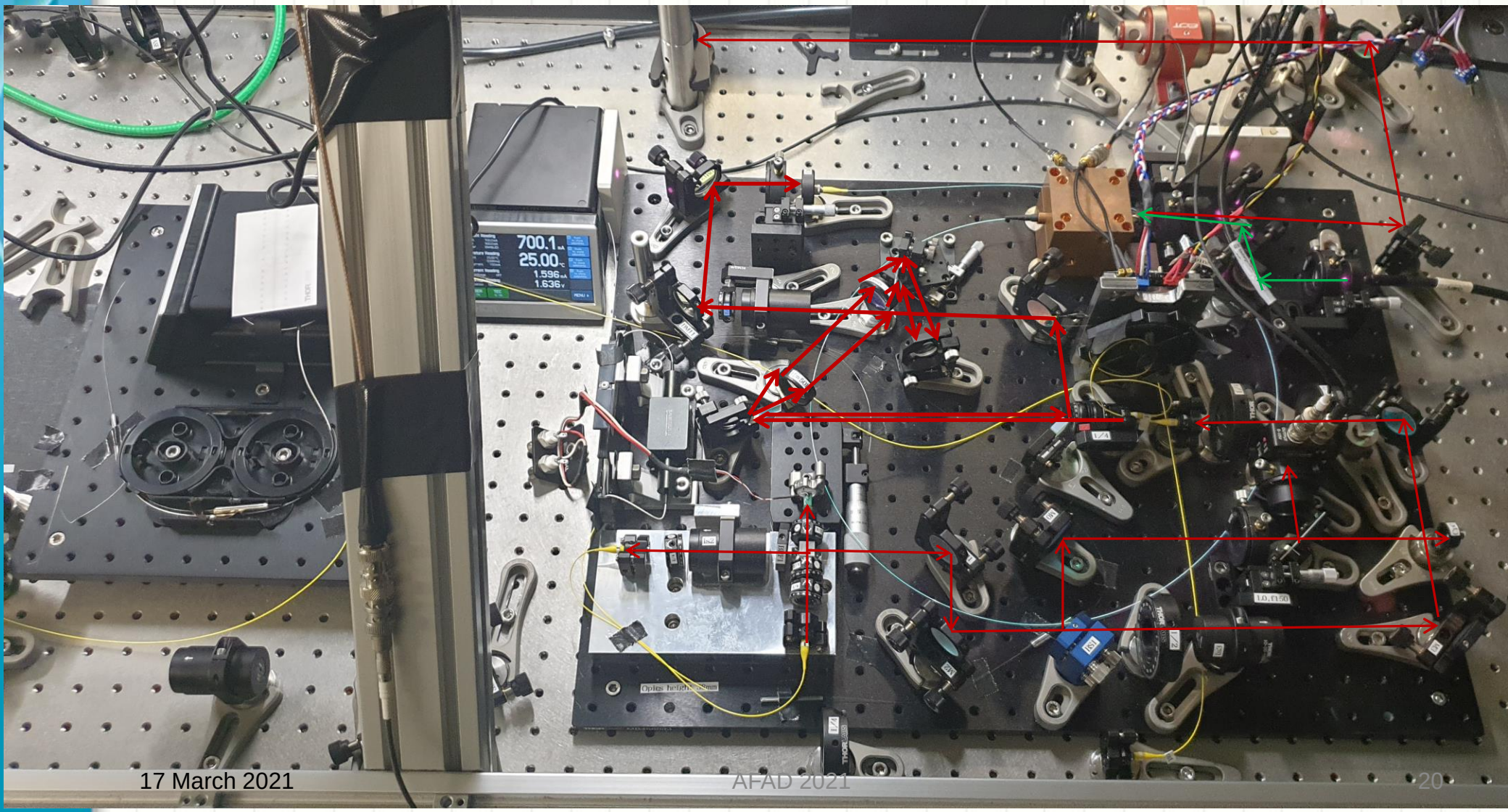


No ASE filters
After PPAmp

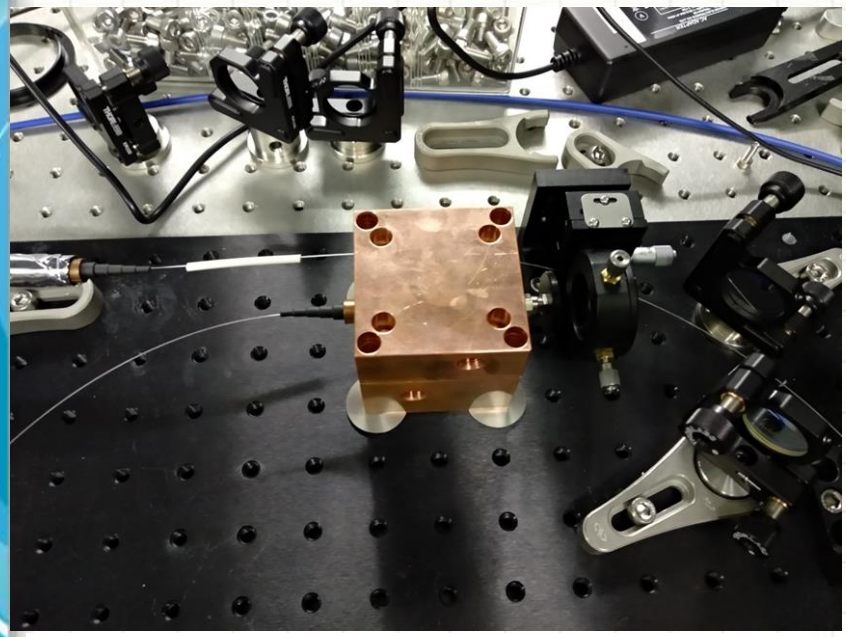
- 2 ASE filters after PPAmp ->>
  - DC ASE reduction = 1.95x
  - Pulsed ASE reduction = 2.45x

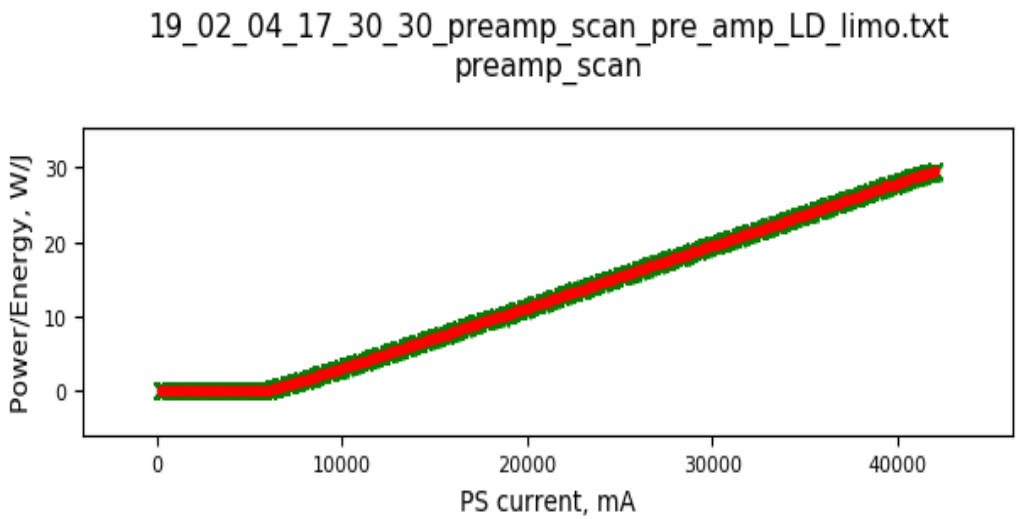


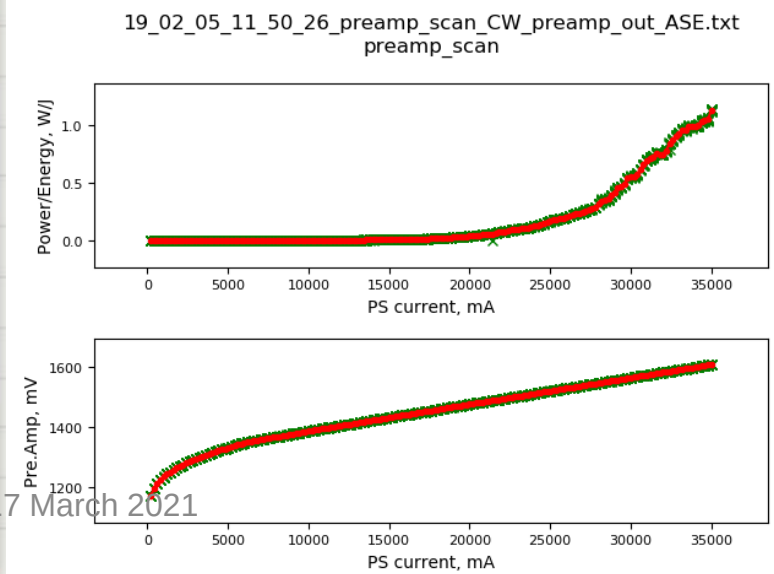
Oscillator, Pulse picker, Pre. Amp

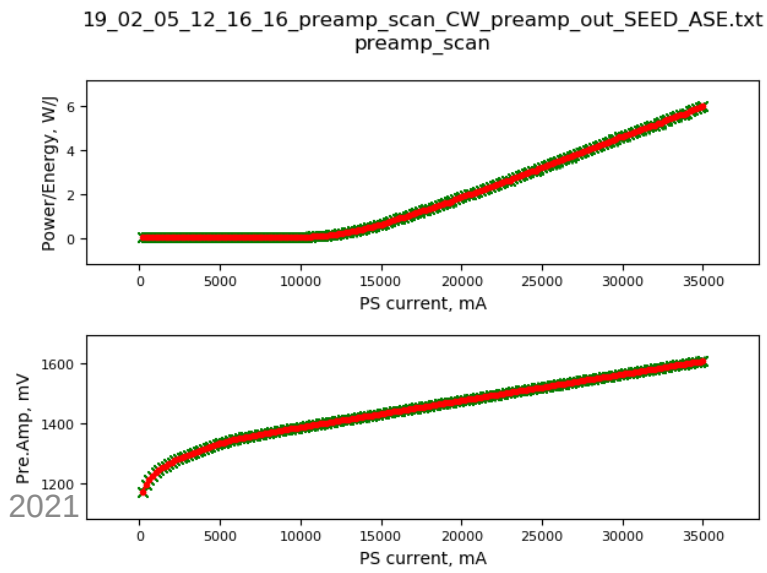


Pre. Amp tests (CW pumping and seeding)

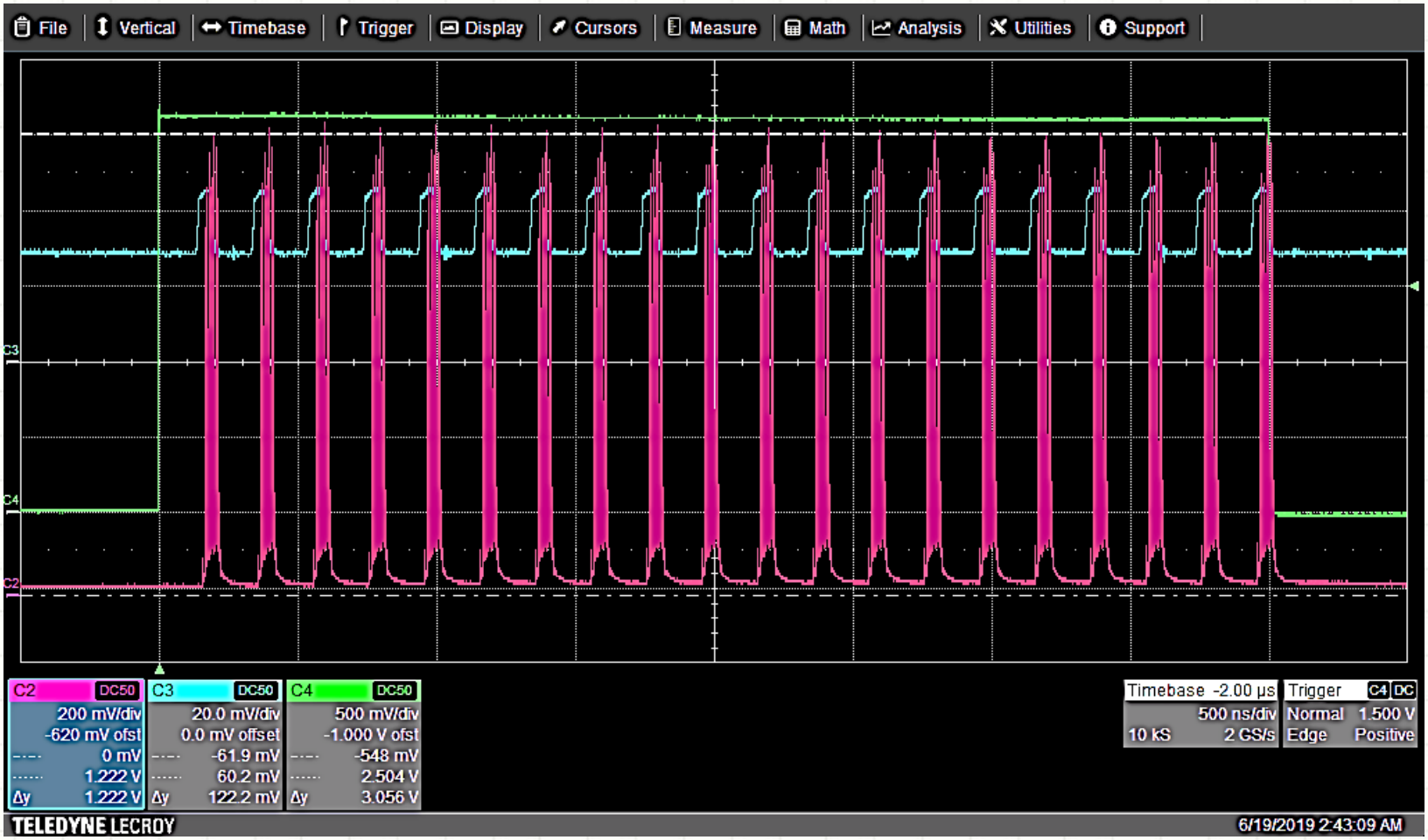






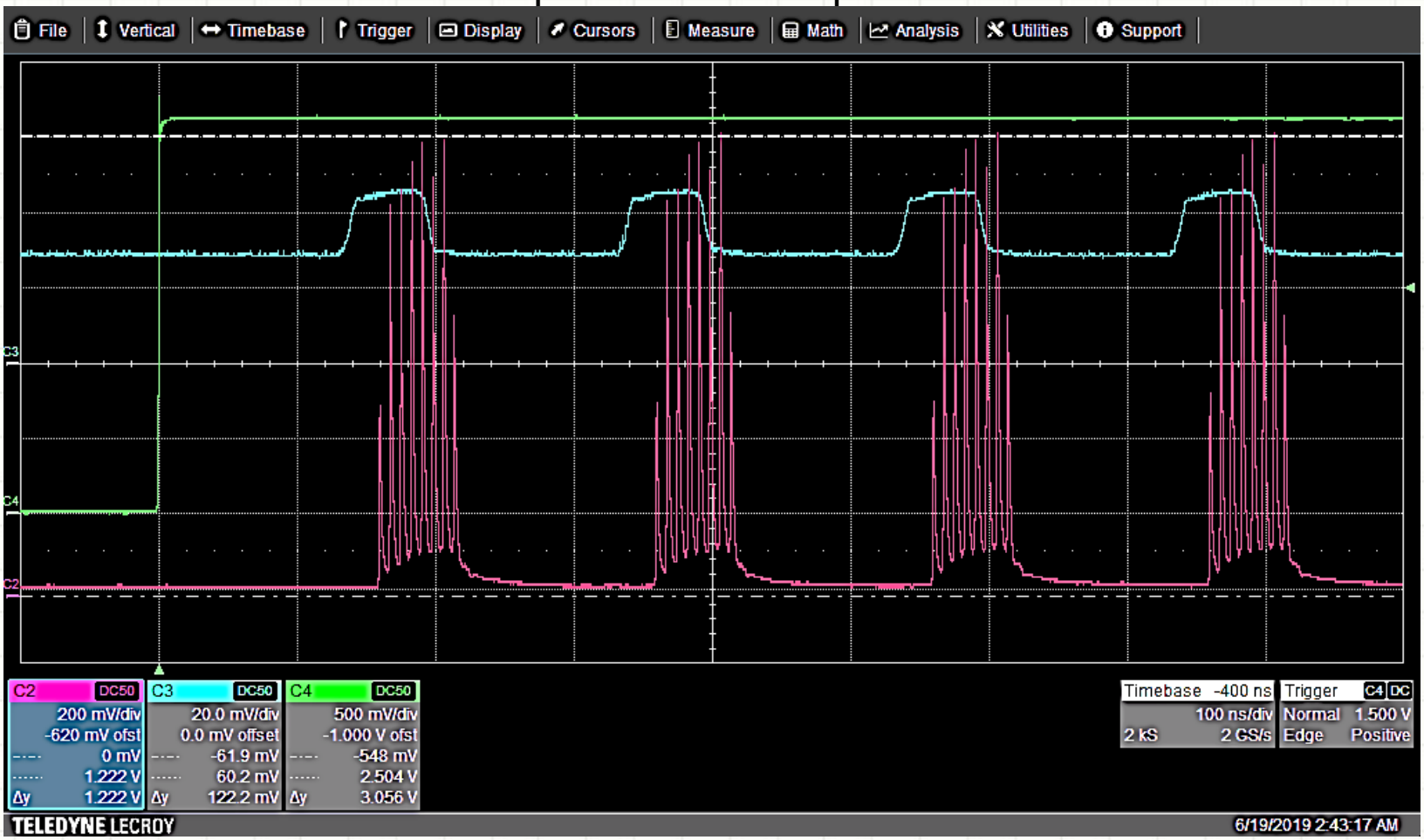


Pre. Amp output (pulsed seeding)



Pre. Amp output (pulsed seeding)

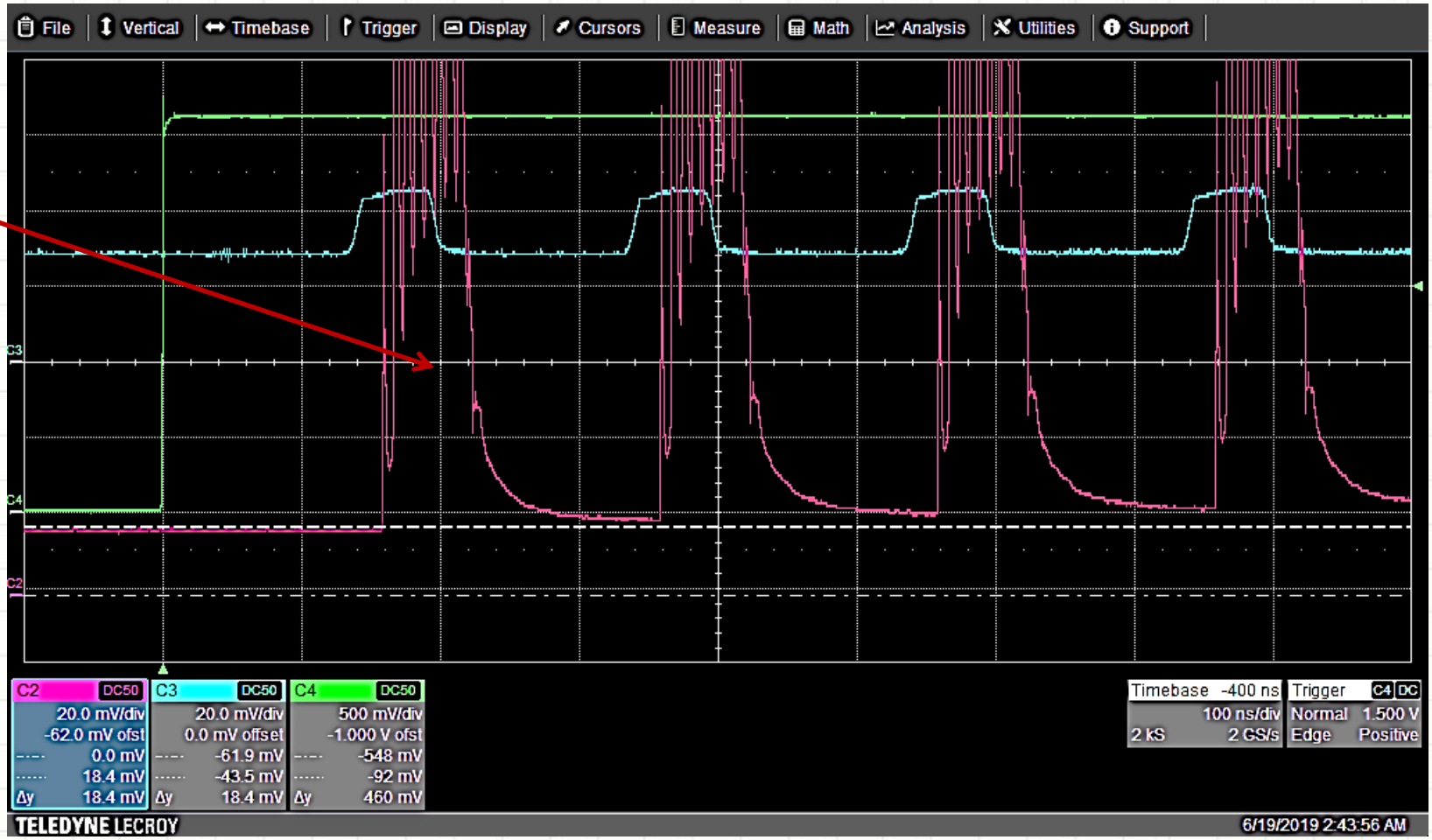
60uJ for **20x7.8** pulses = **384nJ**/pulse



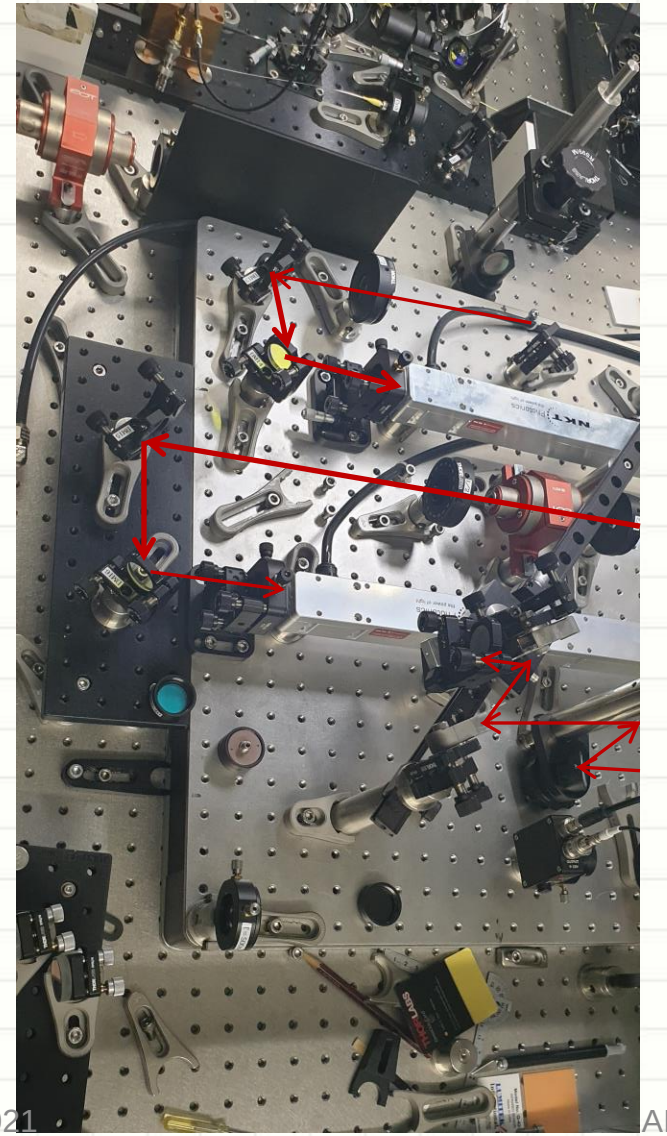
Pre. Amp output (pulsed seeding)

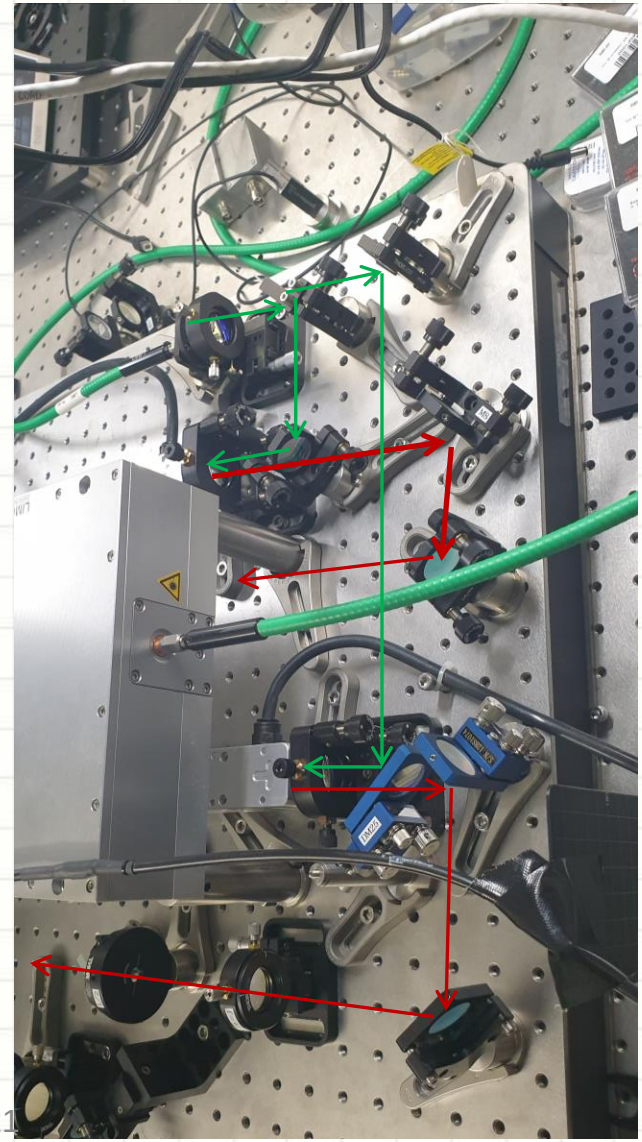
Pulsed ASE
From SOA
Can be killed
By reducing
SOA gain

CW ASE
From Pre.Amp
Broad spectrum
Larger spread

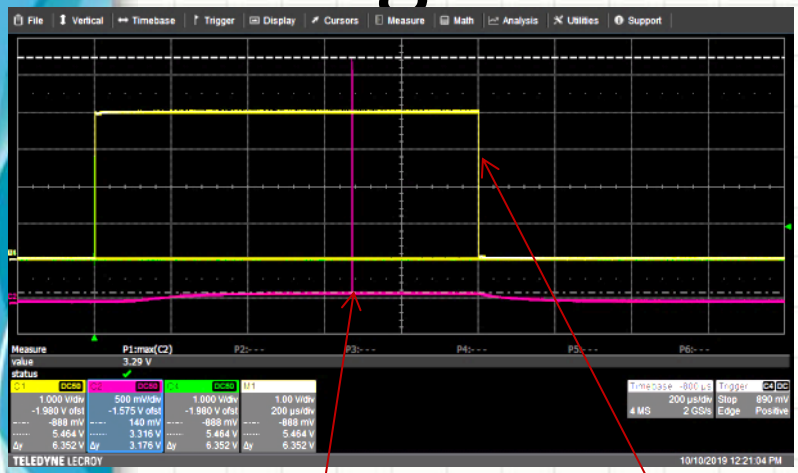


Main Amplifiers





Timing and ASE



PD signal

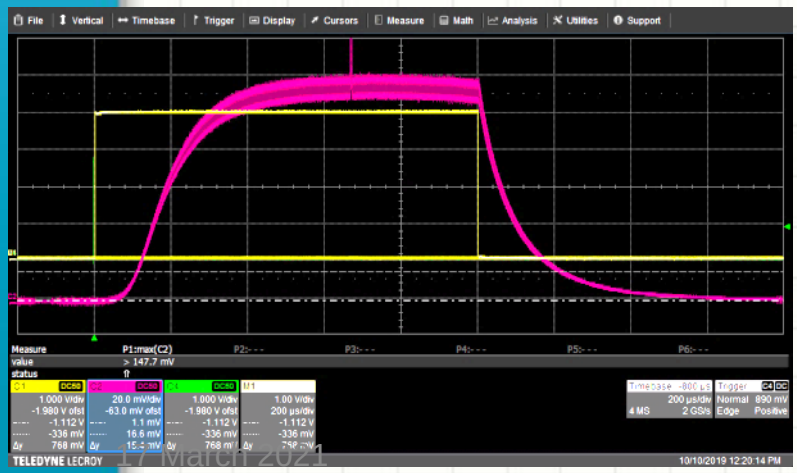
Pump trigger

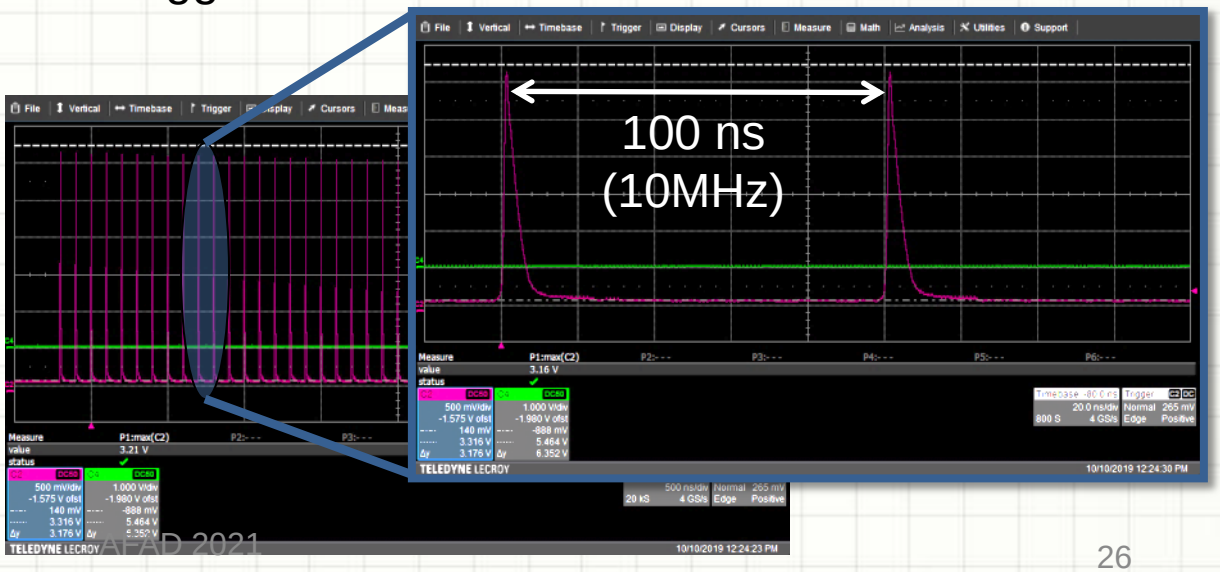
Main trigger

“build-up” time

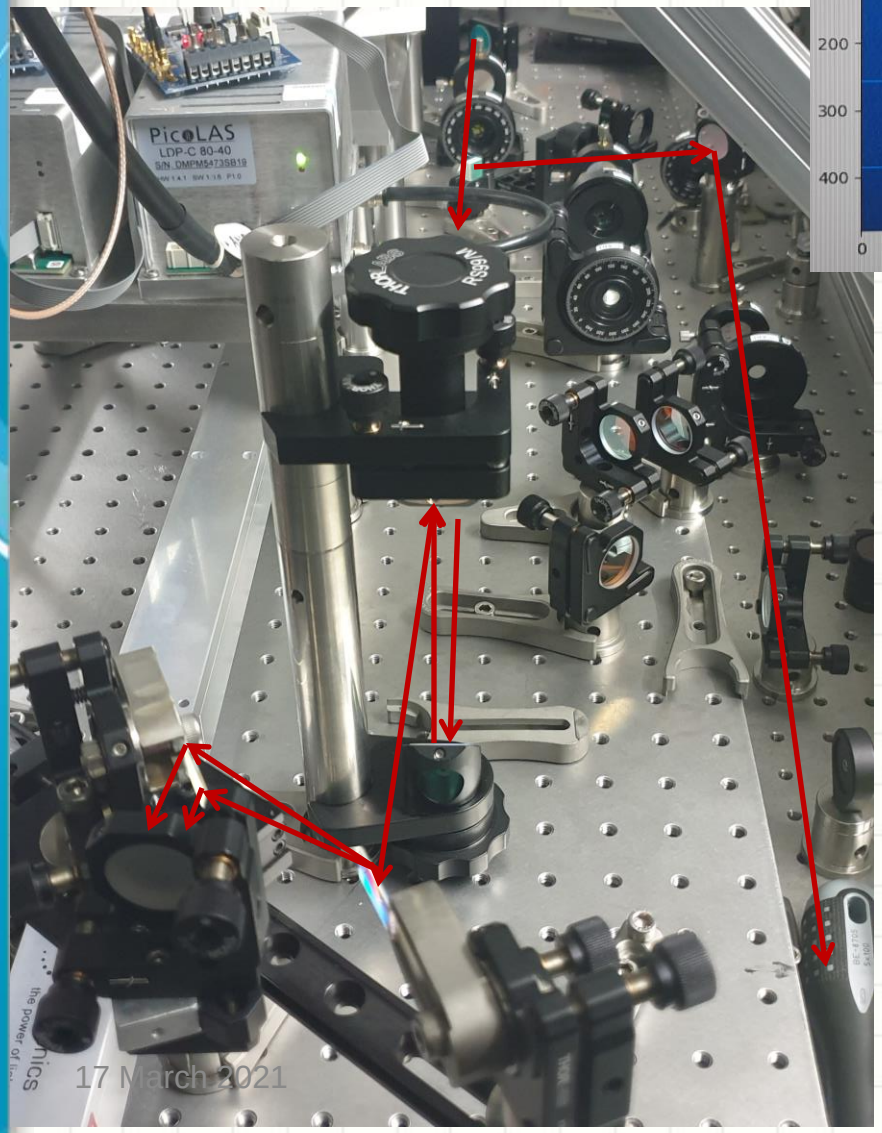
Seeding
~300nJ/pulse
6x130MHz pulses
40x every 10MHz

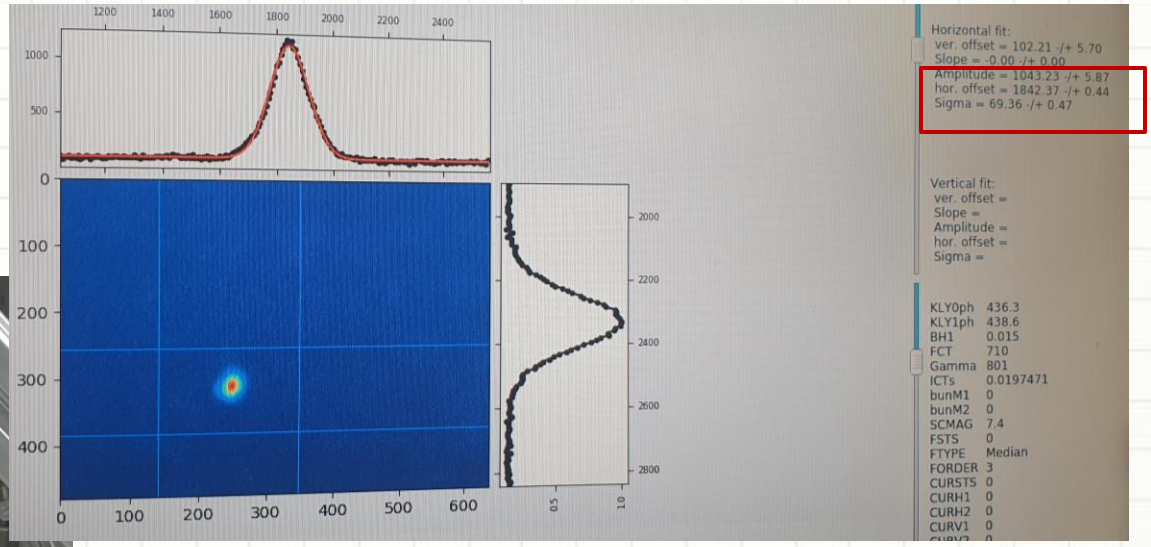
“loading” ~ 6.6% is visible





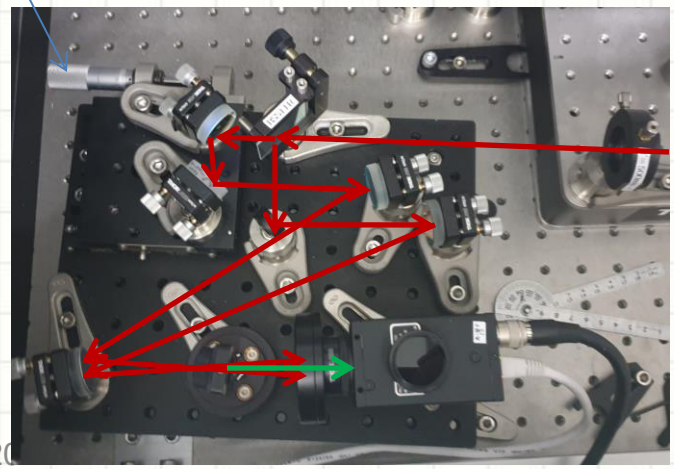
Compressor and Autocorrelator



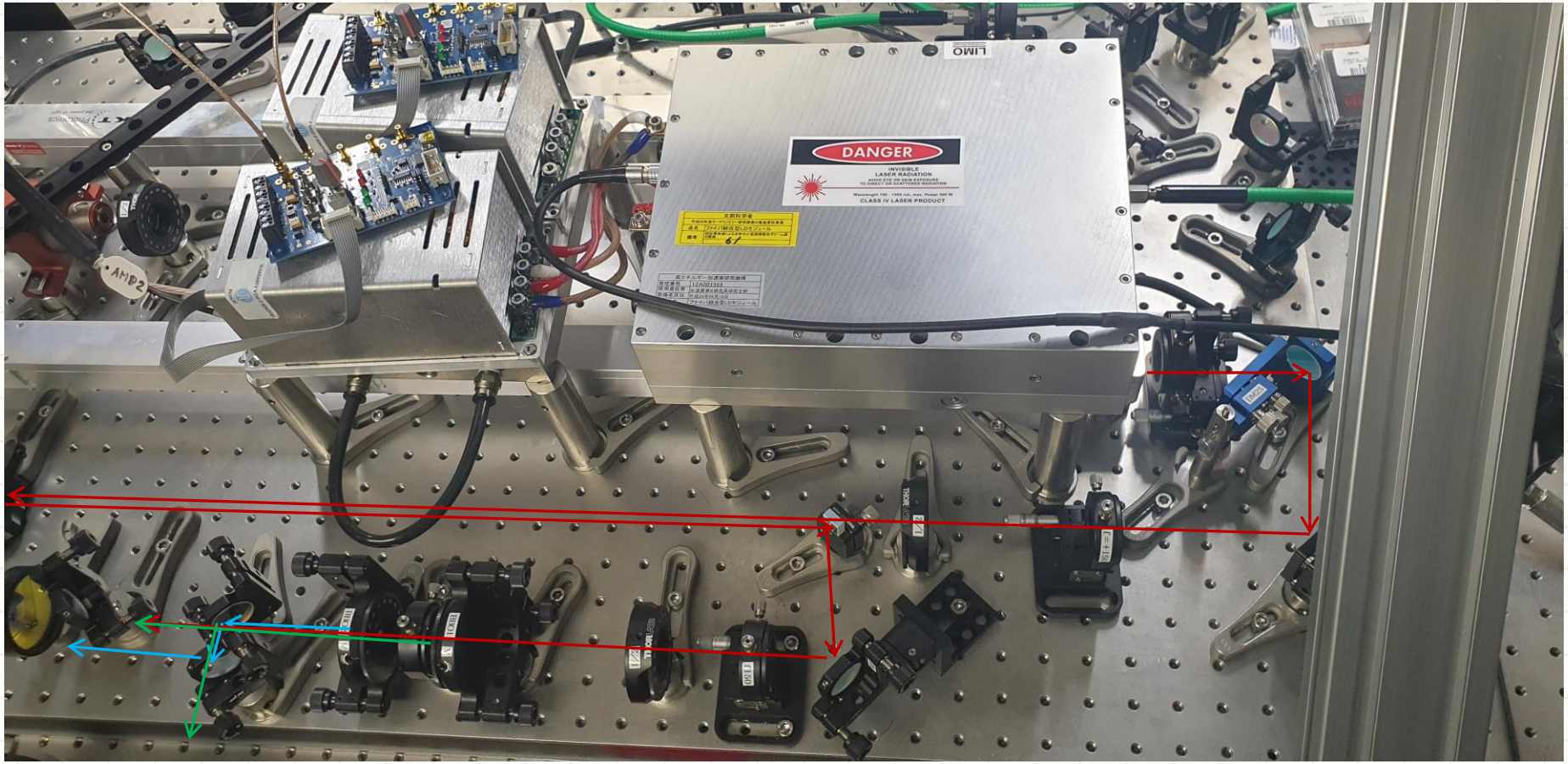


0 um – 1829 pix
20 um – 1842 pix

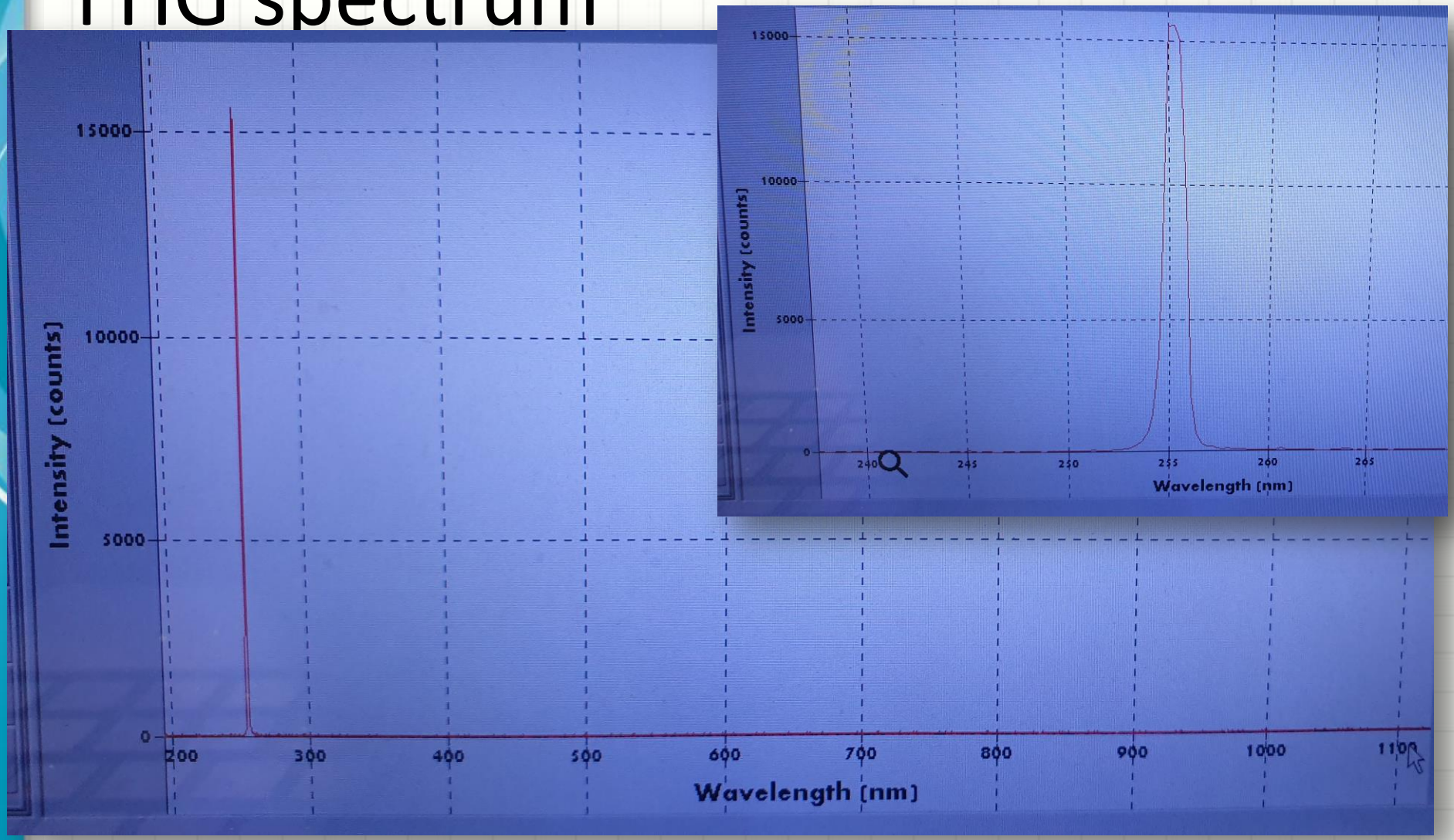
20um –> 66.74fs = 13 pix
5.13 fs/pix
69 pix = 354 fs



Fourth Harmonic Generation (FHG)

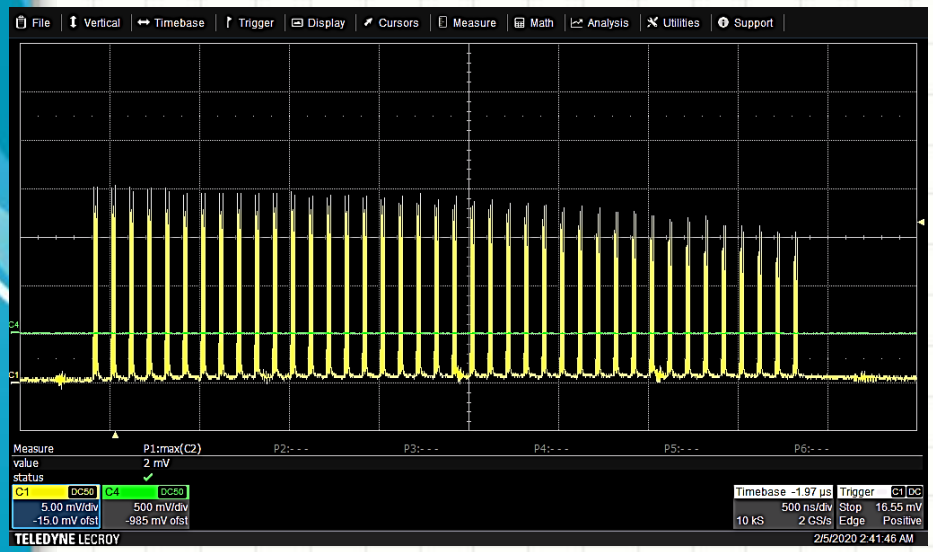


FHG spectrum

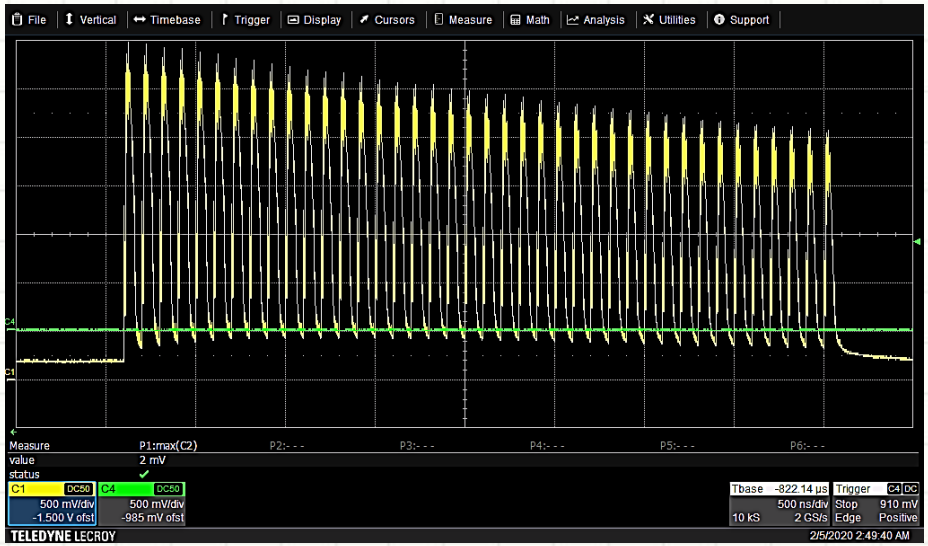


PD signal before and after FHG

4th Harmonic



Fundamental harmonic after compressor



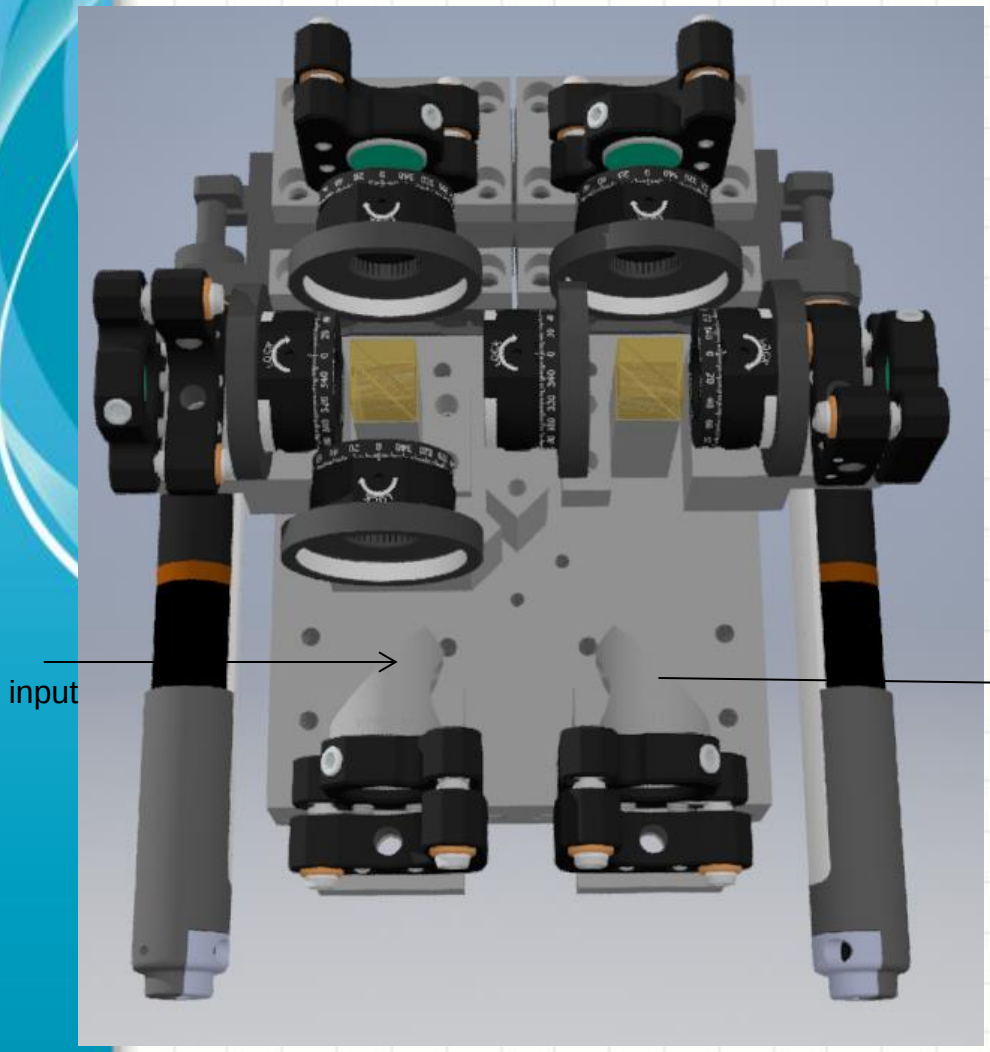
~ 30 uJ / pulse @ 255nm, ~ 2% rms stability (1 min), ~ 3% rms stability (1 hour)

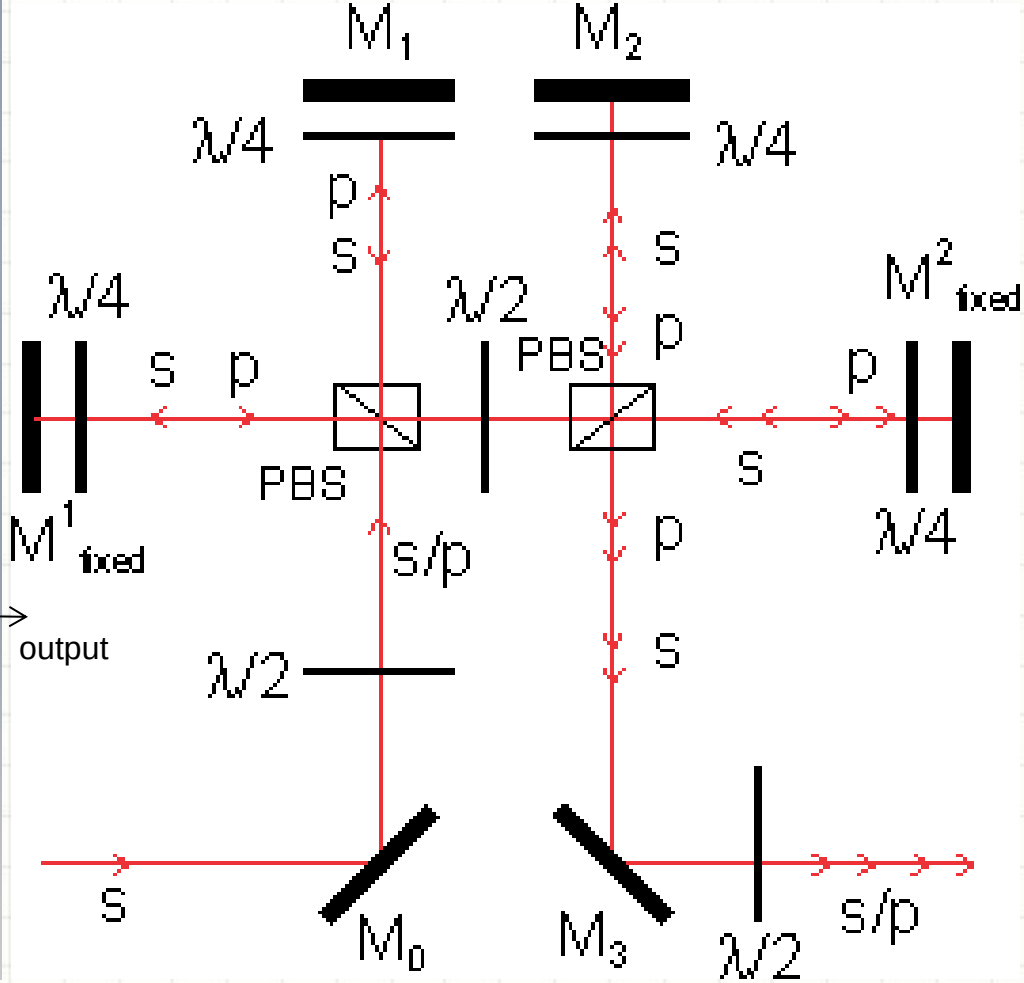
CW and pulsed ASE is completely removed

FHG energy improvements

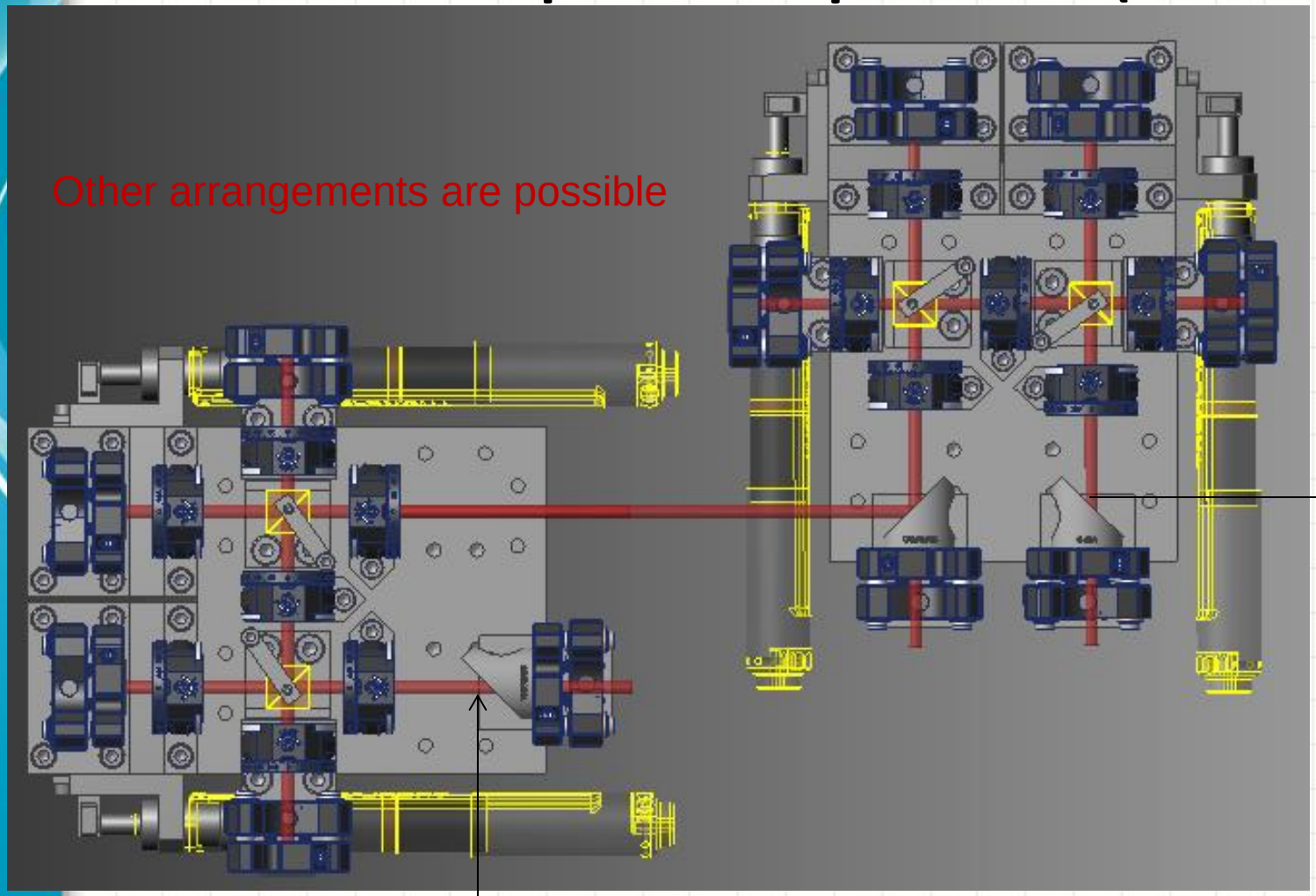
- Higher E / pulse
  - Pre-pre Amplifier tuning (reduction of Yb fiber length)
  - Better tuning of the whole laser (polarization map should be checked)
  - Better FHG tuning
- Higher E and shorter pulses
  - Better tuning of the stretcher/compressor (geometry + focusing)

Laser pulse splitter





16x Laser pulse splitter (buncher)

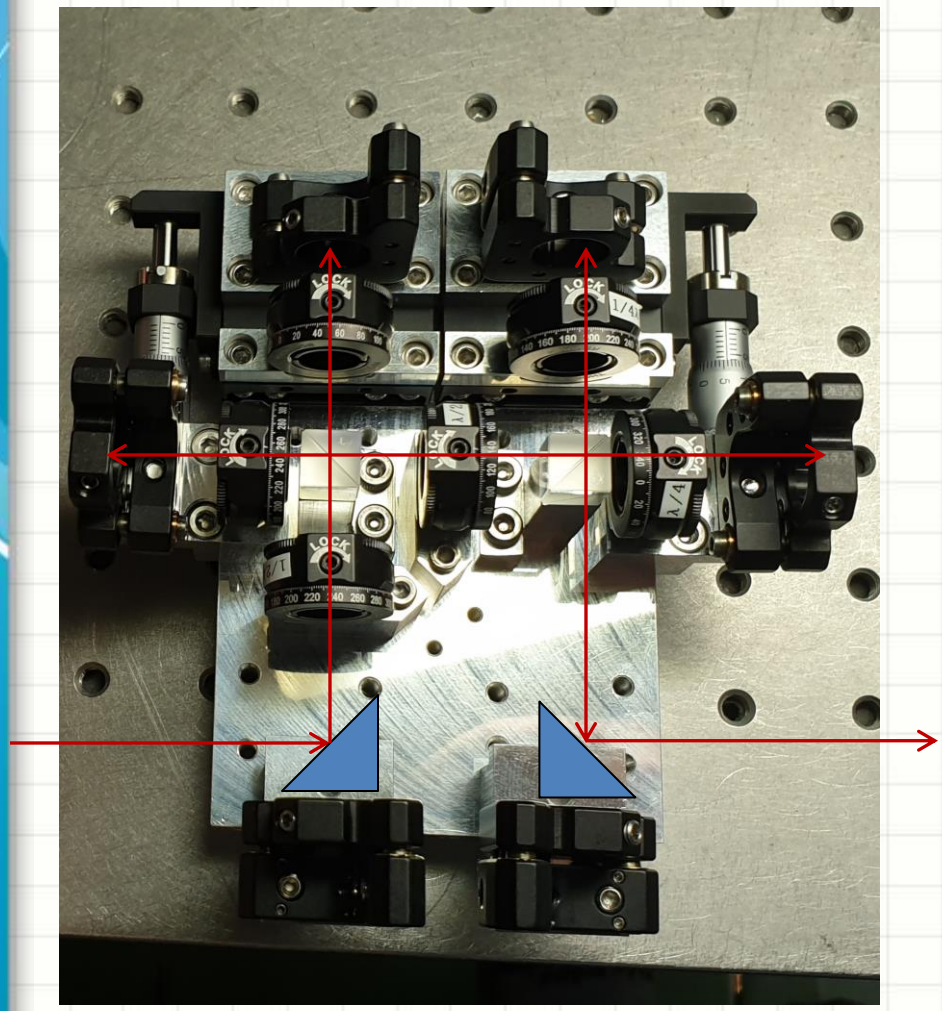


output

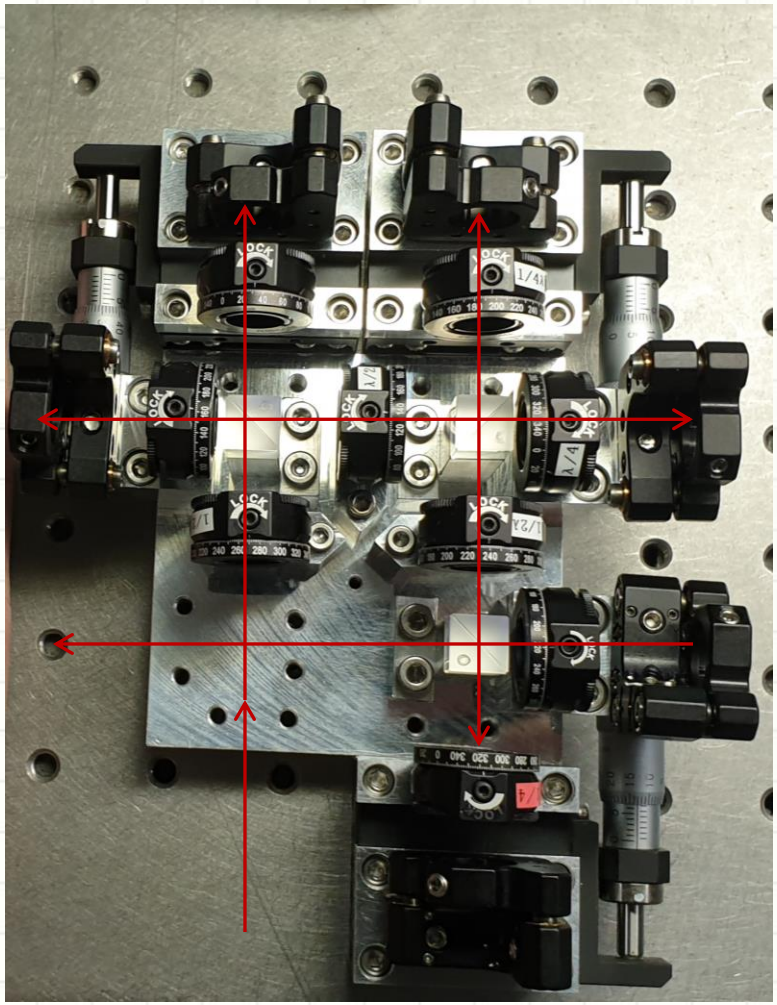
input

Laser “Buncher”, IUAC manual type

4x



8x



Summary

- Yb-dopped fiber laser shows better stability and handling than Ti:Sa laser.
- In terms of laser pulse duration at the Cs2Te cathode, they both can achieve comparable values of 150-200 fs.
- However, the total number of bunches / machine cycle is much higher for Yb laser (MHz rep.rate).
- Final system tuning is on-going.
- Completion and e-beam tests of the Yb laser is expected in the spring of 2021.

Thank you for your attention