Laser chirping to enhance the LGS return flux via reducing spectral hole burning effects

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Motivation

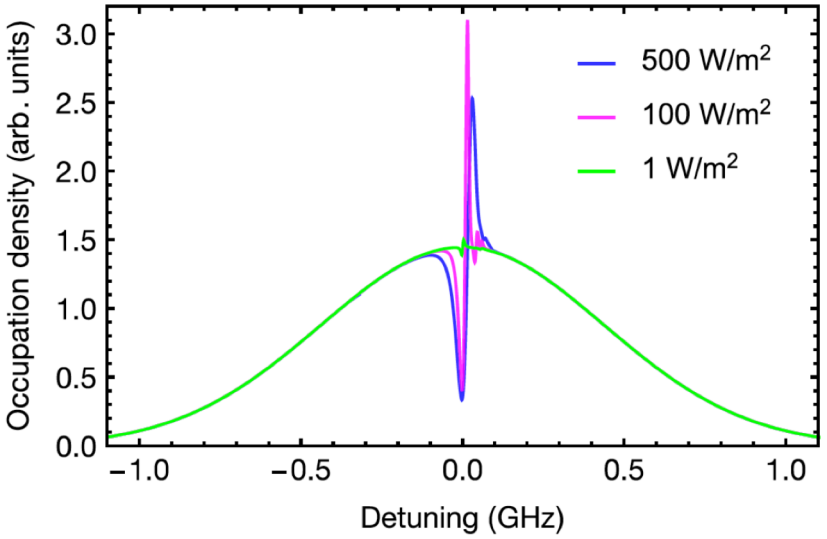
- Increasing LGS return flux, an LGS-AO system can operate:
  - at faster speed [strong wind, daytime LGS-AO]
  - with smaller subapertures. [worse seeing, shorter wavelengths]
  - lower Sodium levels [lower ALT, low Sodium season]

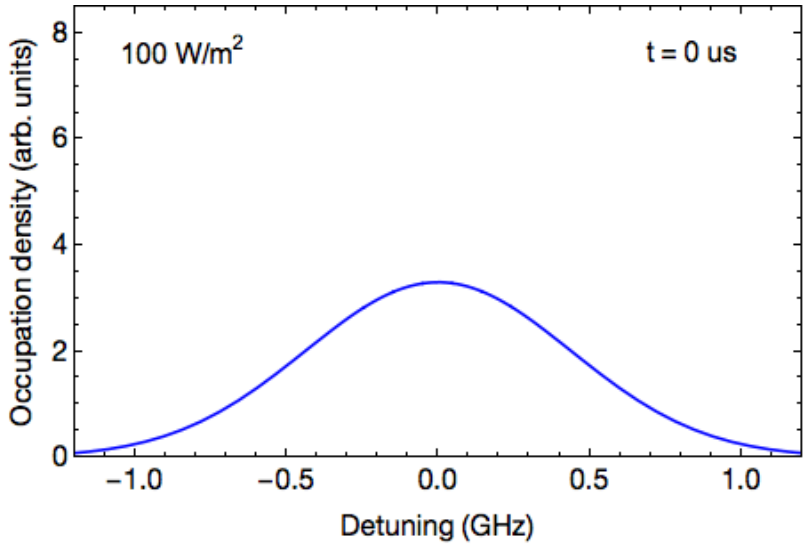
- 74W CW: one launch telescope can create more than one LGS (MAVIS, GTC). (Pierre Haguenauer previous talk)

- Space awareness and Sat-Comm require 75W CW or more (ESO-ESA collaborative framework). ALASCA project: TRL6 LGS-AO 24/7, PAA LEO, MEO, GEO orbits

Spectral hole burning

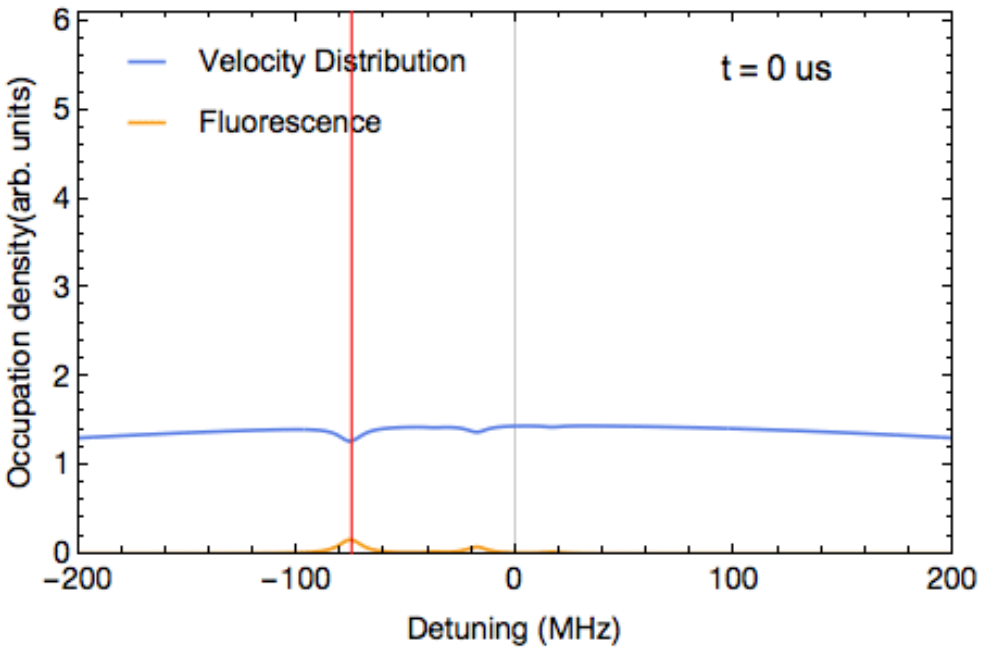
- Doppler velocity distribution (1 GHz FWHM on D_2 line).
- Single-frequency laser excitation (at D_2a center).
- Spectral hole burning with increasing irradiance.
- Atoms drift to next velocity class due to recoil.



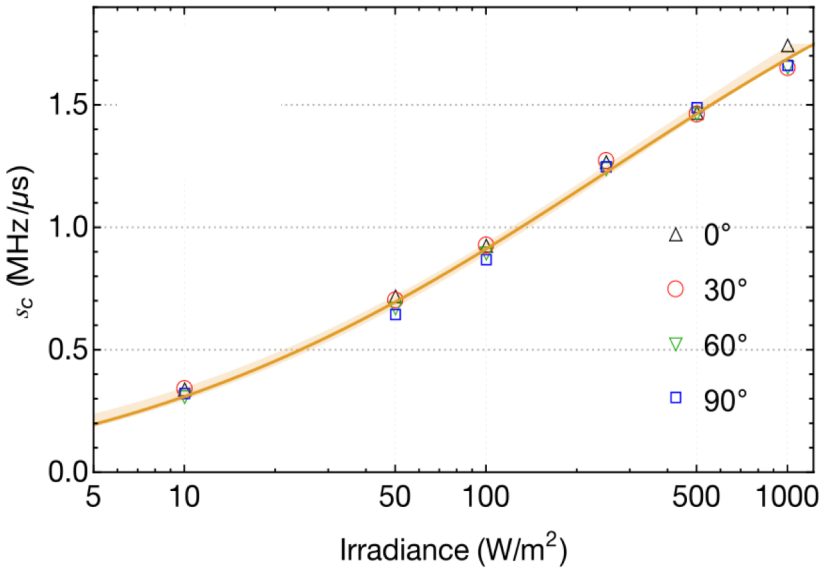


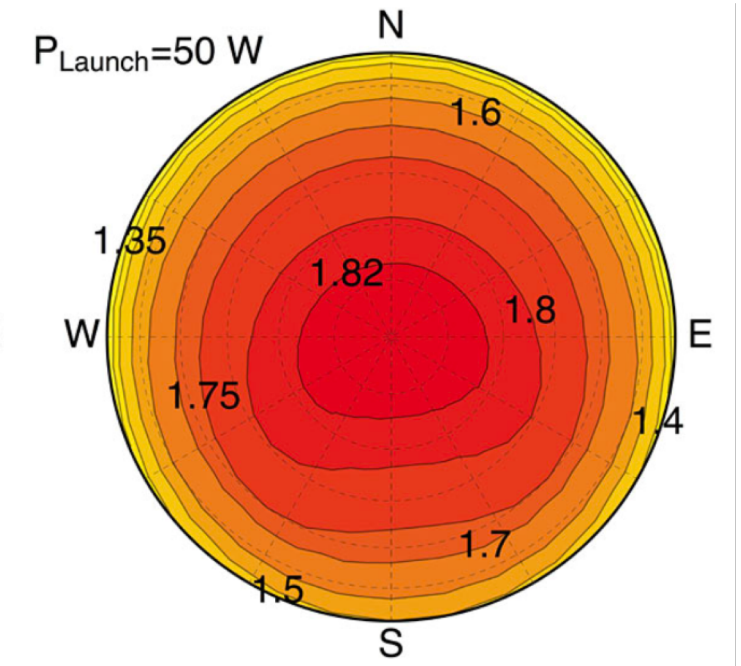
Chirping

- Linear sweep in optical frequency (chirp)
- Chirped laser tracks atomic populations drift
  - Reduces spectral hole burning
- Maximized optical excitation → **higher return flux**



Modeling

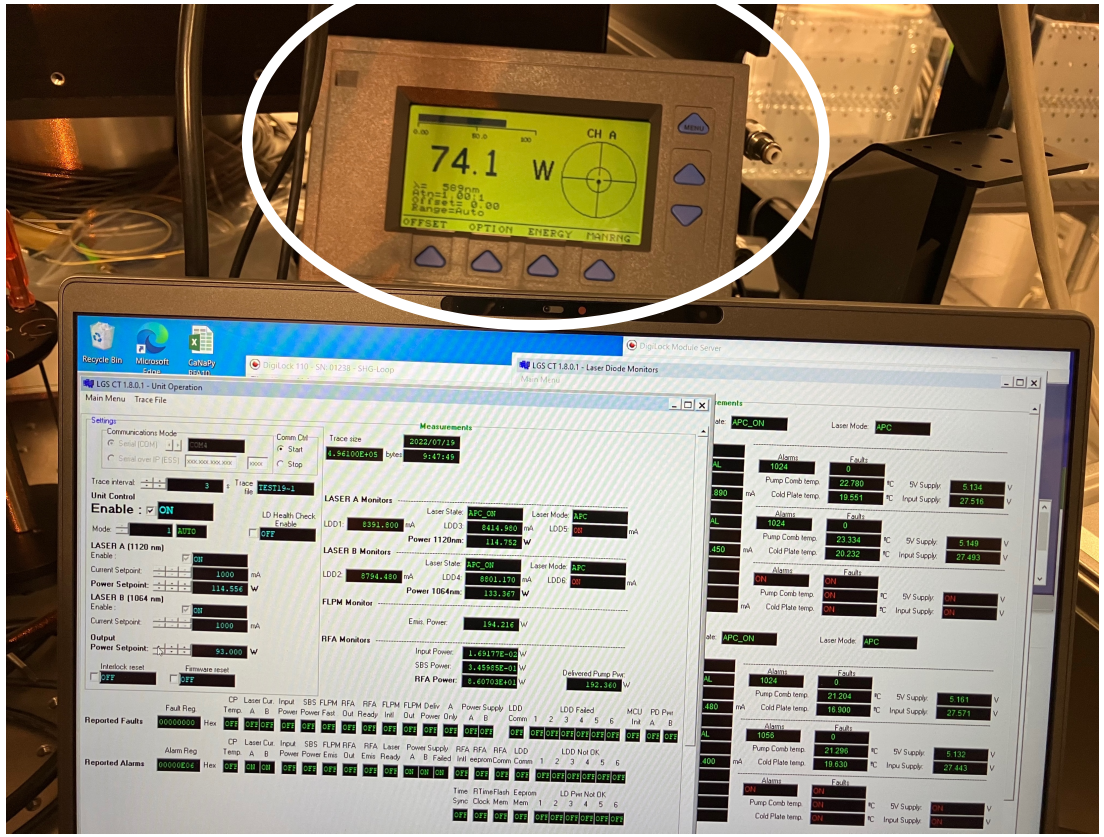




- ❑ Rochester Scientific's LGSBloch package
- ❑ Atmospheric modeling (Na profile, molecular collisions, spot profile, etc.)
- ❑ Optimal chirp rate dependence of irradiance
- ❑ Return flux enhancement of x1.8 at 50W

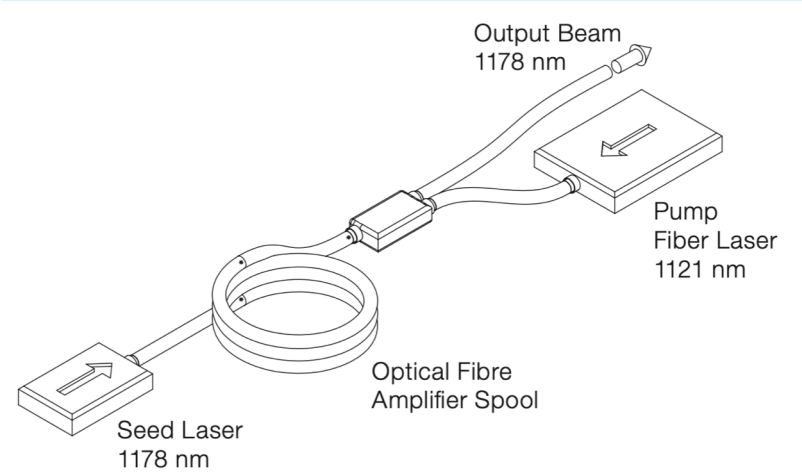
70W+/589nm laser

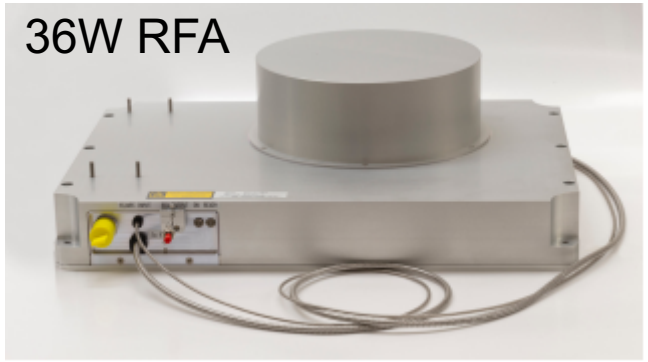
2021 at Allgäuer Volkssternwarte Ottobeuren - AVSO

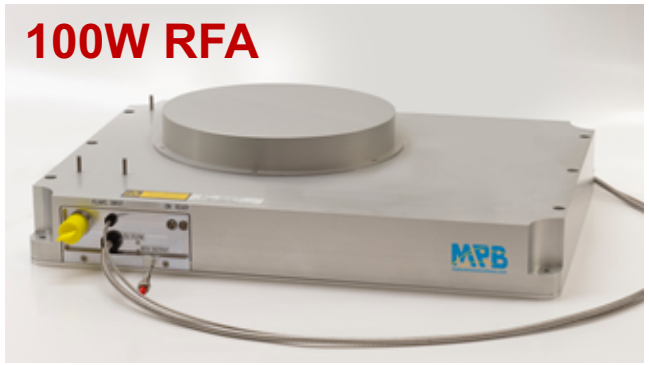


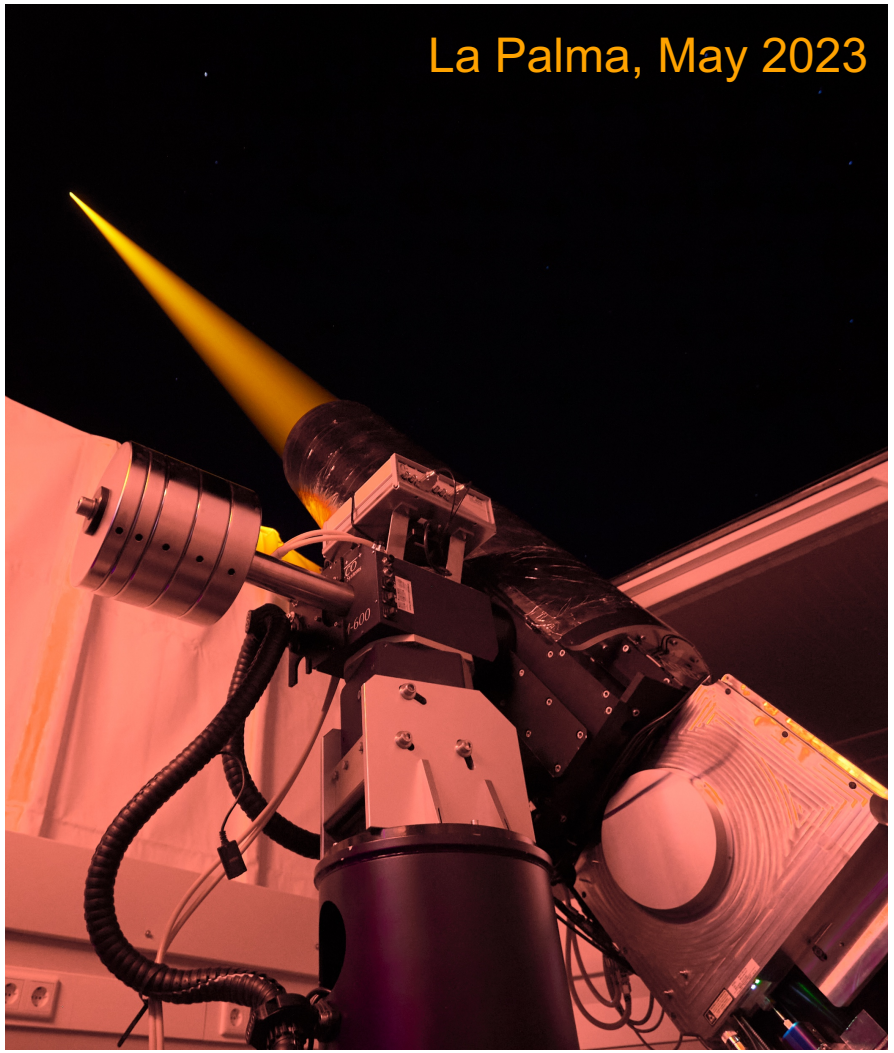
70W+/589nm laser

- ESO/MPBC/TOPTICA effort to upgrade Wendelstein Laser Guide Star System (WLGSU)
- 200-W 1120-nm fiber pump laser enclosure identical to the one of *SodiumStar 20/2*
- The fiber laser power supply (FLPS) enclosure is identical to the one of *SodiumStar 20/2*
- The 100-W RFA enclosure identical footprint and smaller height than the *SodiumStar 20/2*

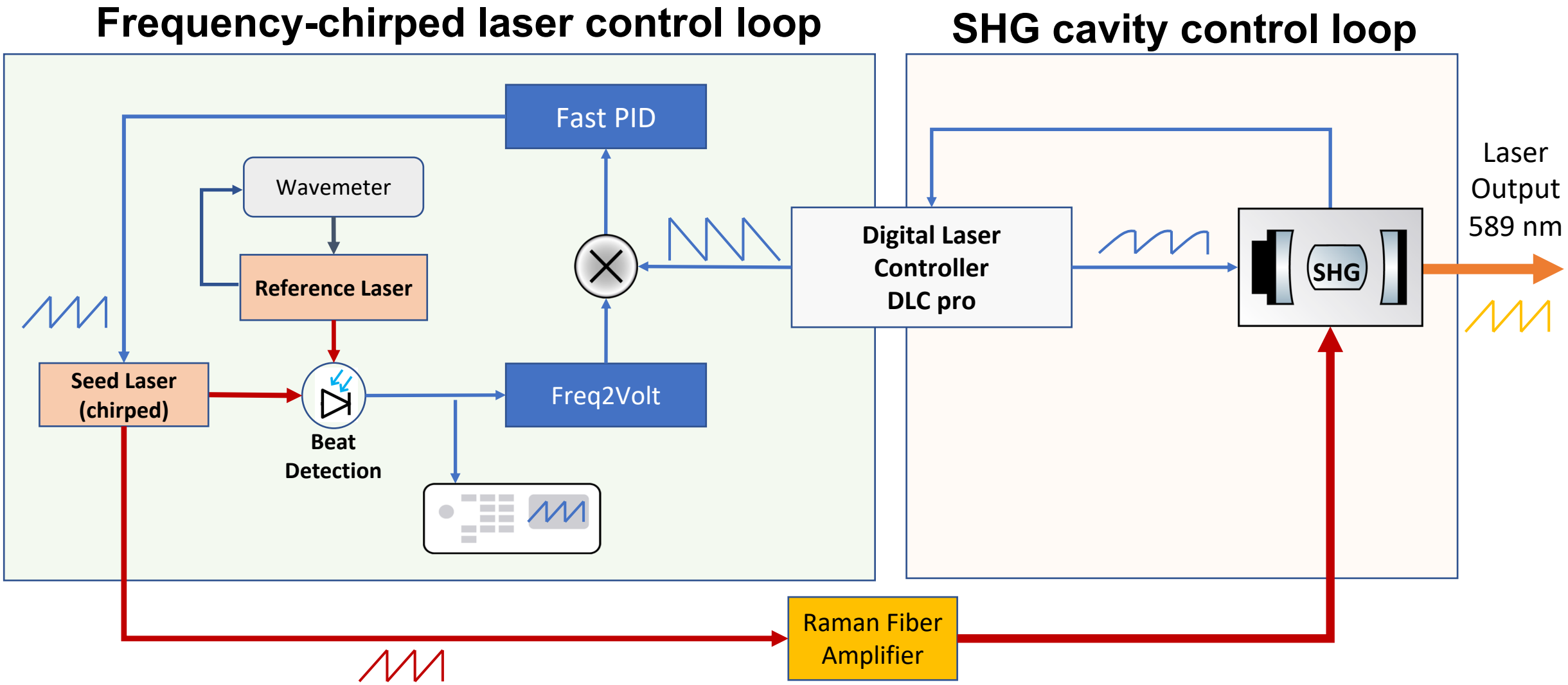








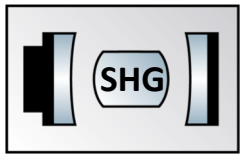
Laser chirping - Implementation

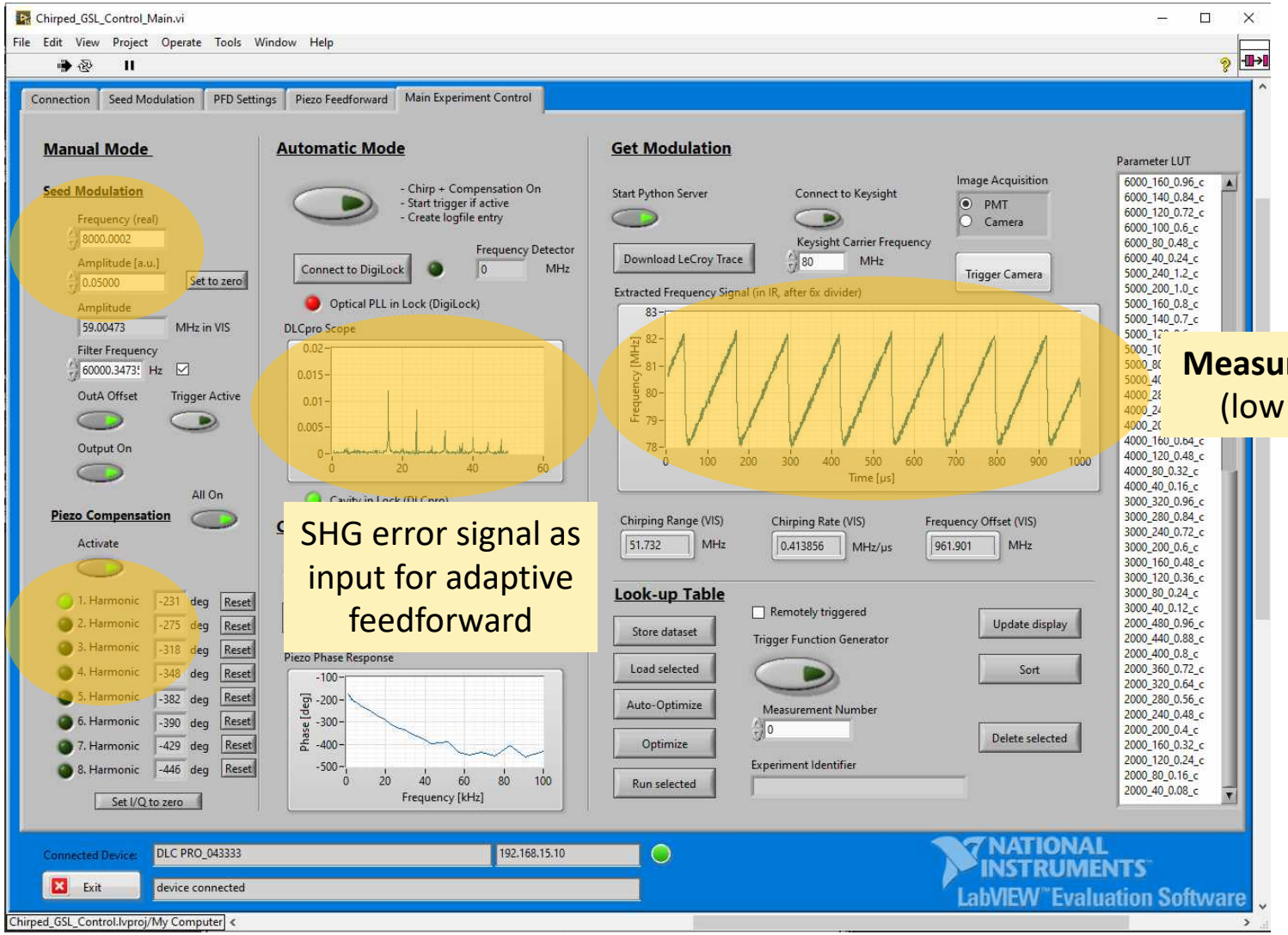


Laser chirping – Software interface

Modulation setting (here 8 kHz)

Choice of compensated harmonics (here only #1)



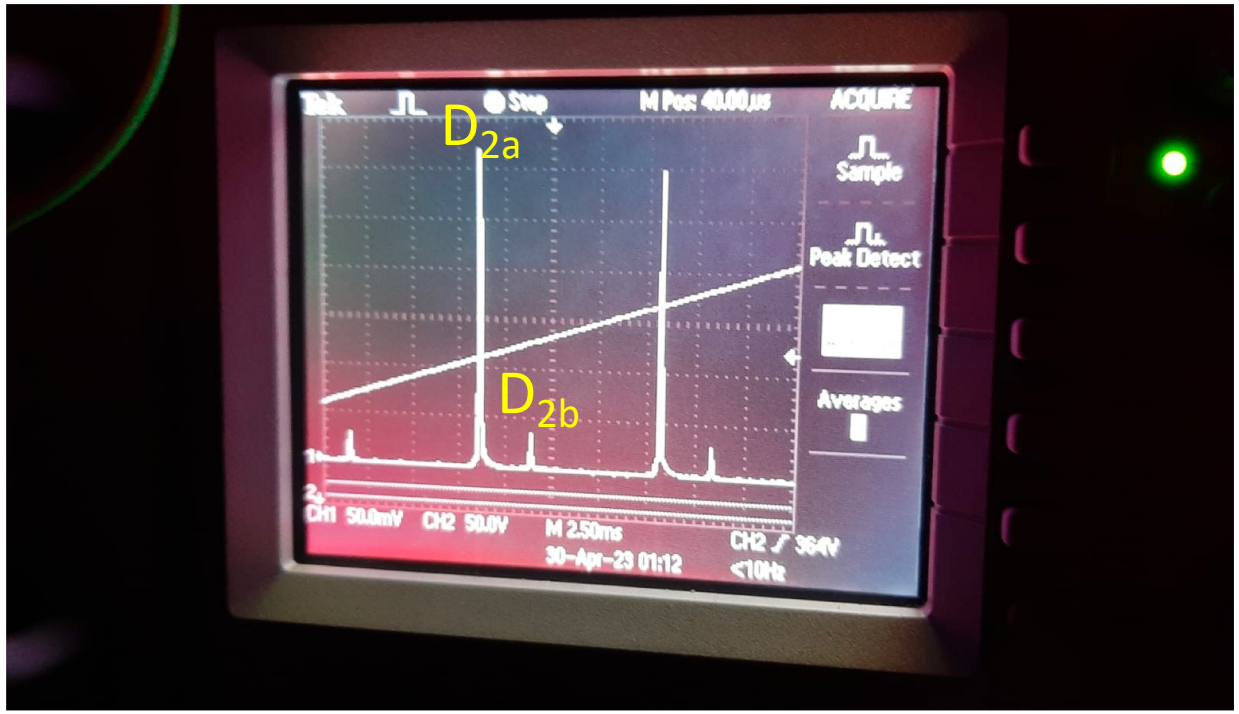


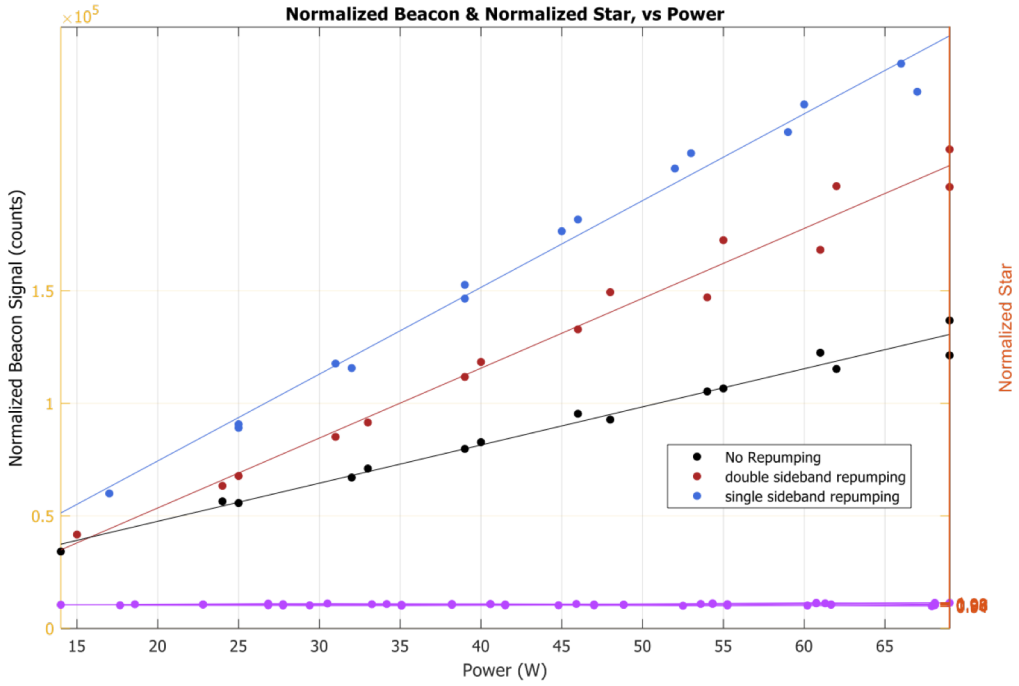
SHG error signal as input for adaptive feedforward

Measured frequency (low power - IR)

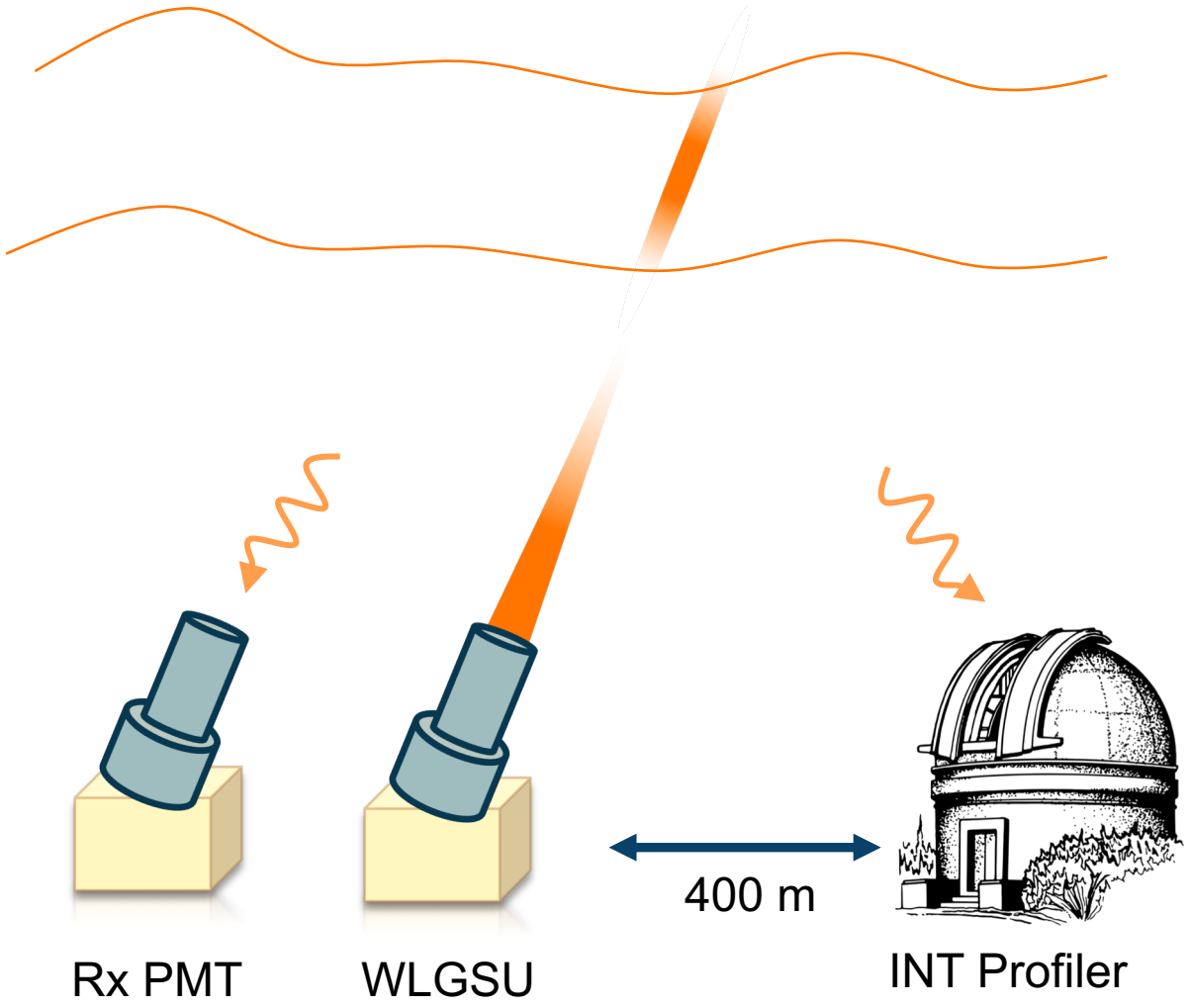
Repumping with single sideband

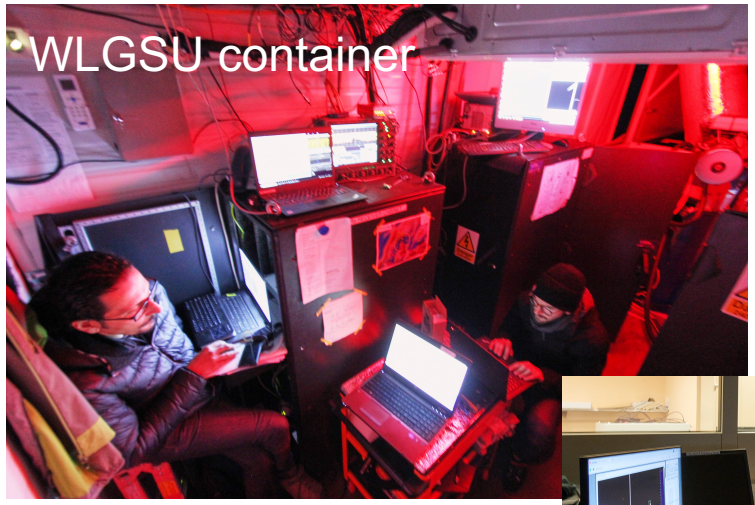
Laser spectrum - Single sideband emission





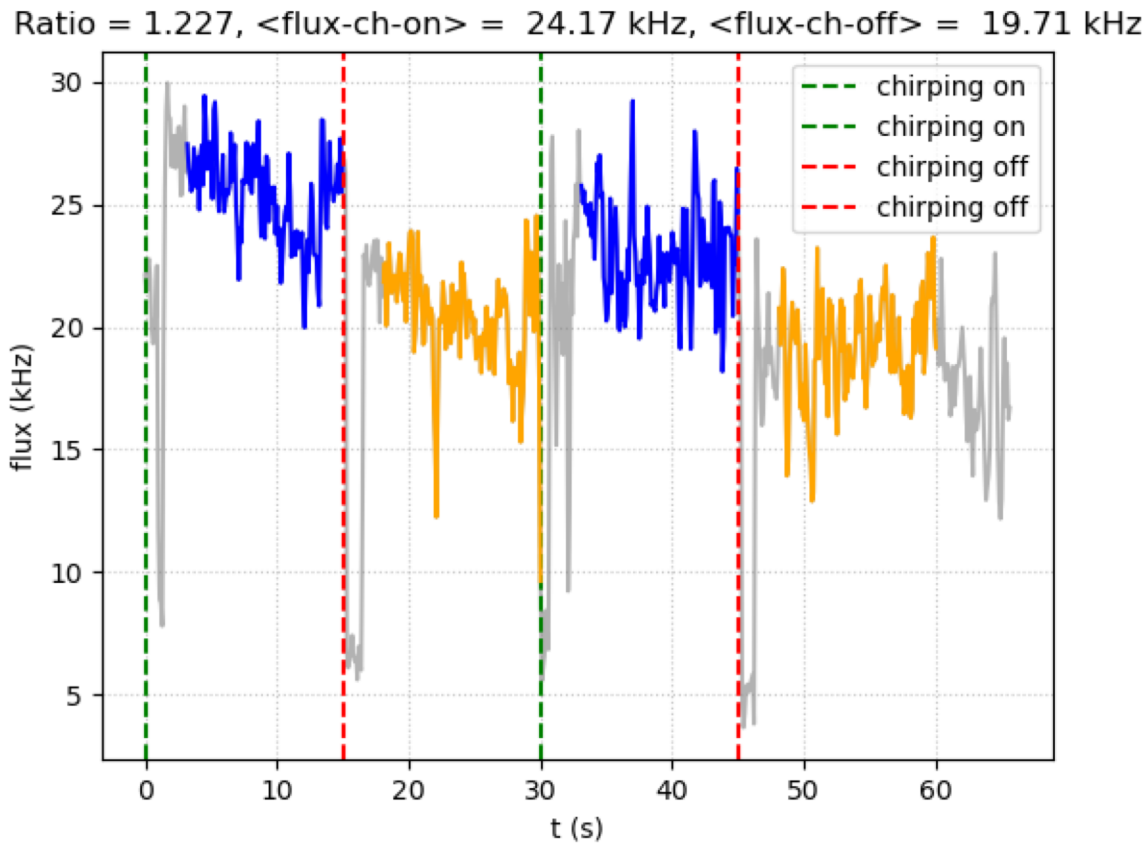
Experiment in La Palma (May 2023)



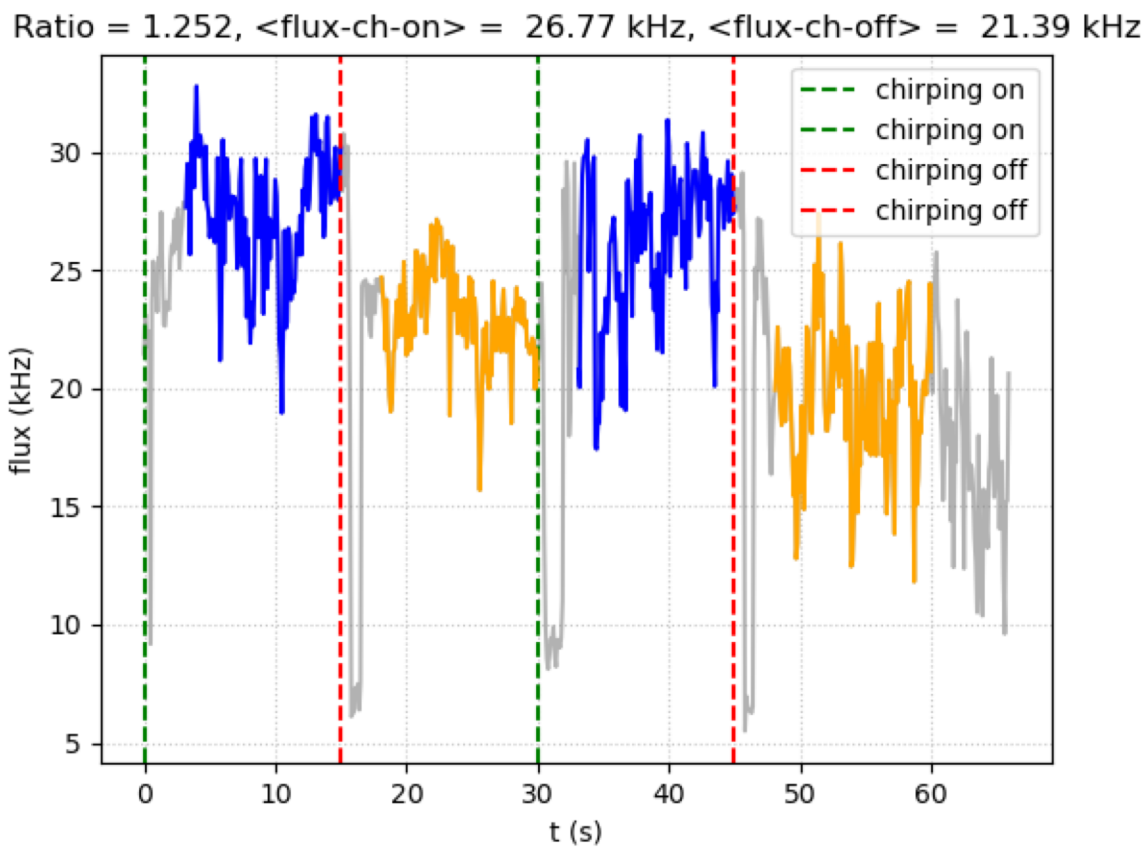


Results – Rx PMT

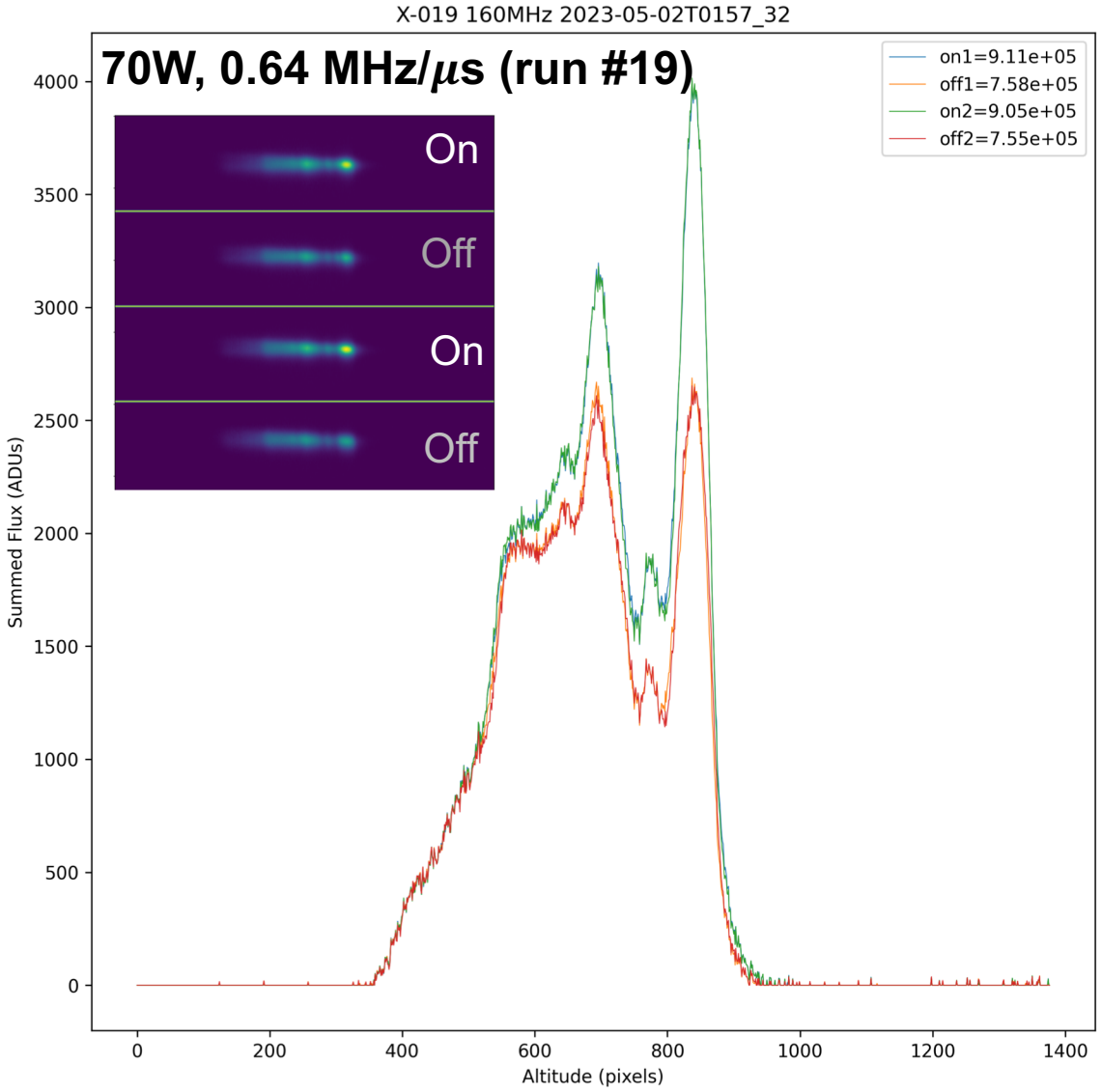
70W, 0.64 MHz/μs (run #19)

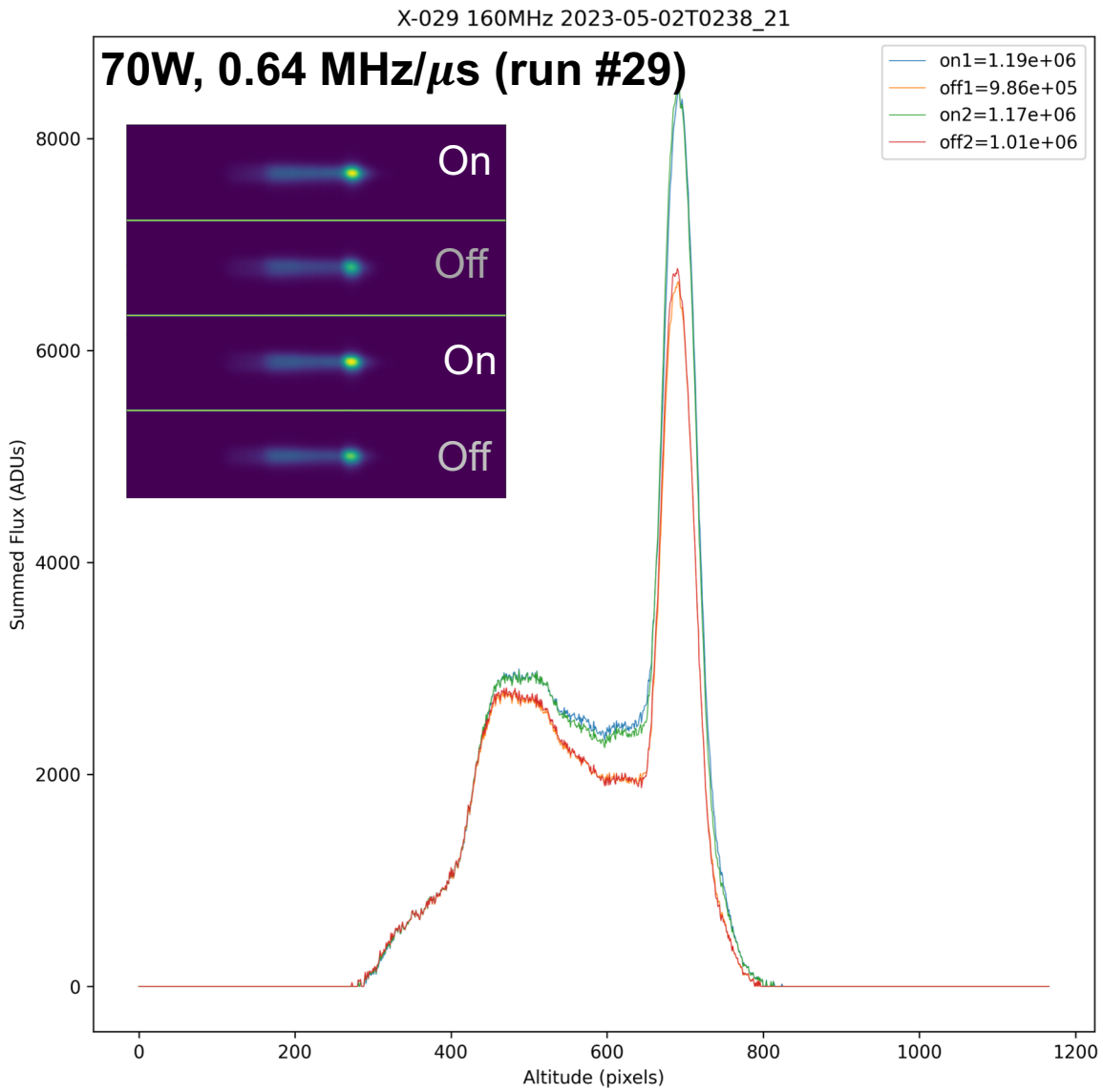


70W, 0.64 MHz/μs (run #29)



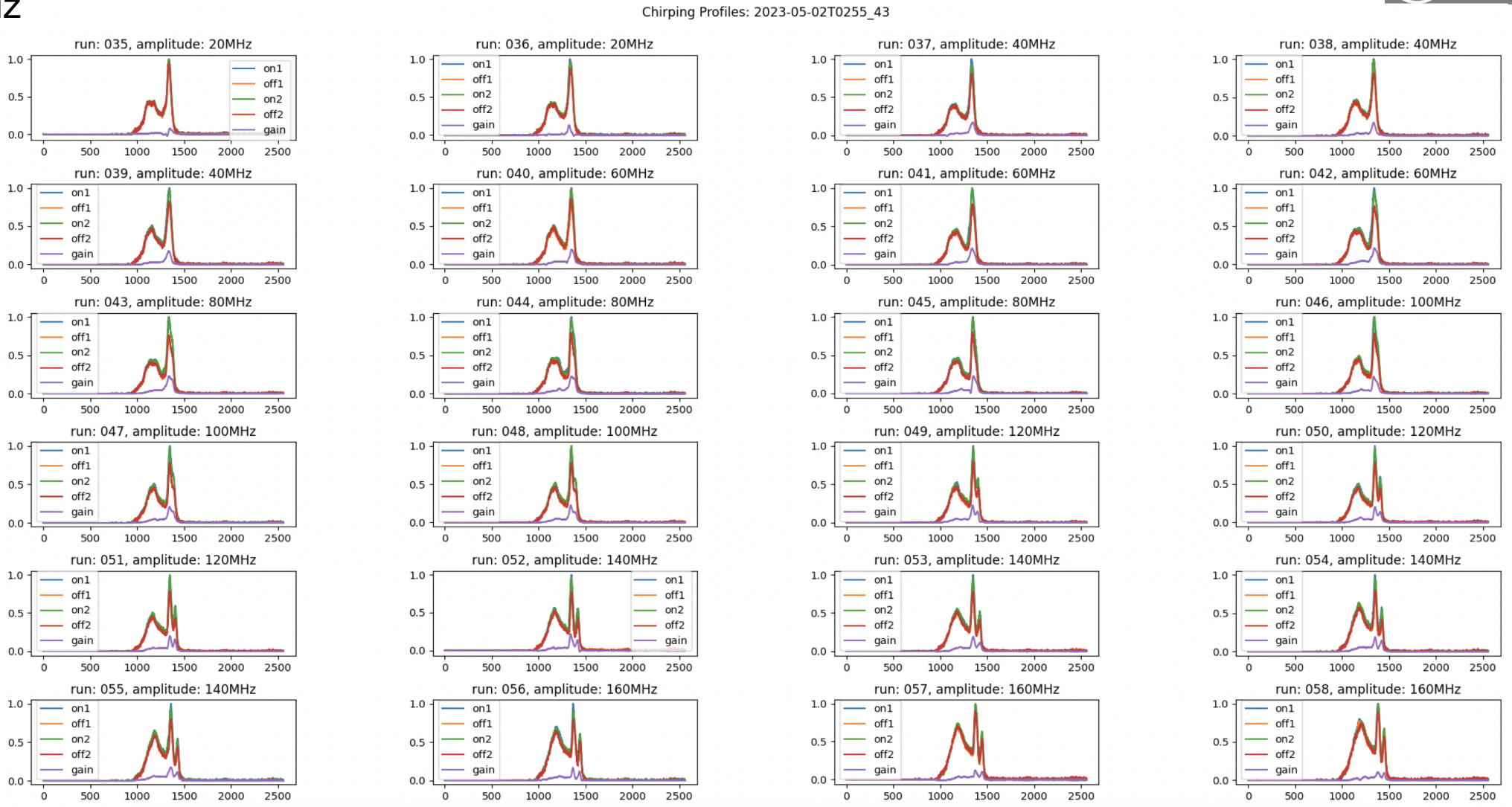
Results – INT Profiler





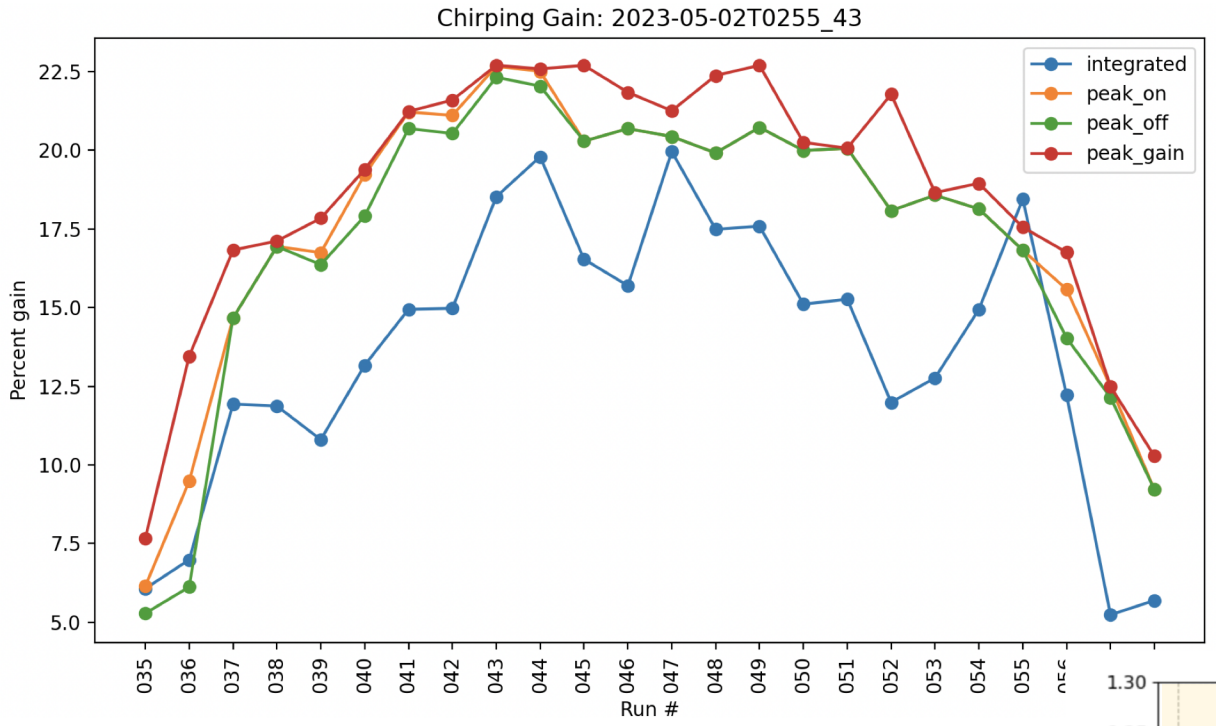
Results – INT Profiles

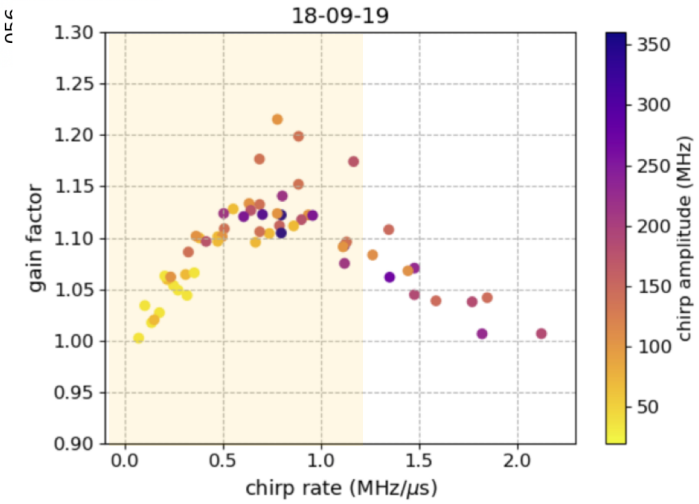
f_{chirp}=8 kHz



Results – Optimum chirp rate

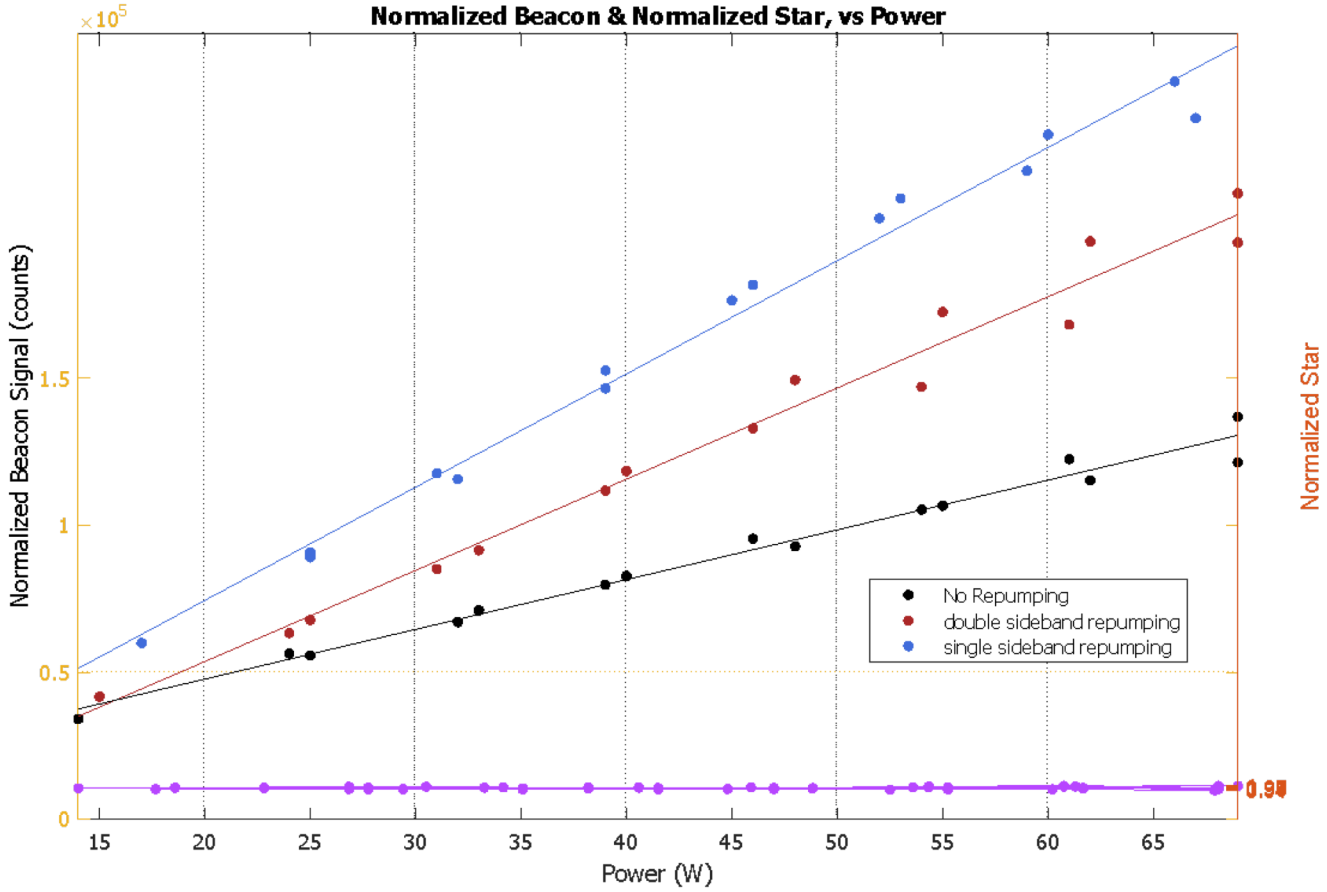
Run #	589 power	Chirp frequency (kHz)	Period (us)	Amplitude VIS (MHz)	Rate (MHz/us)
35	70	8	125	20	0.16
36	70	8	125	20	0.16
37	70	8	125	40	0.32
38	70	8	125	40	0.32
39	70	8	125	40	0.32
40	70	8	125	60	0.48
41	70	8	125	60	0.48
42	70	8	125	60	0.48
43	70	8	125	80	0.64
44	70	8	125	80	0.64
45	70	8	125	80	0.64
46	70	8	125	100	0.8
47	70	8	125	100	0.8
48	70	8	125	100	0.8
49	70	8	125	120	0.96
50	70	8	125	120	0.96
51	70	8	125	120	0.96
52	70	8	125	140	1.12
53	70	8	125	140	1.12
54	70	8	125	140	1.12
55	70	8	125	140	1.12
56	70	8	125	160	1.28
57	70	8	125	160	1.28
58	70	8	125	160	1.28

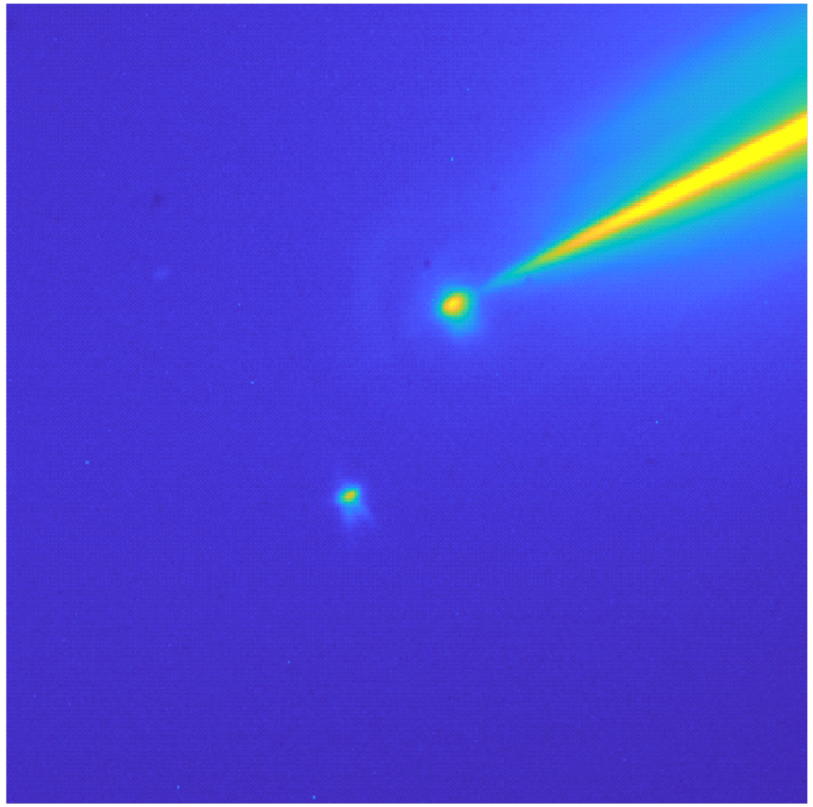




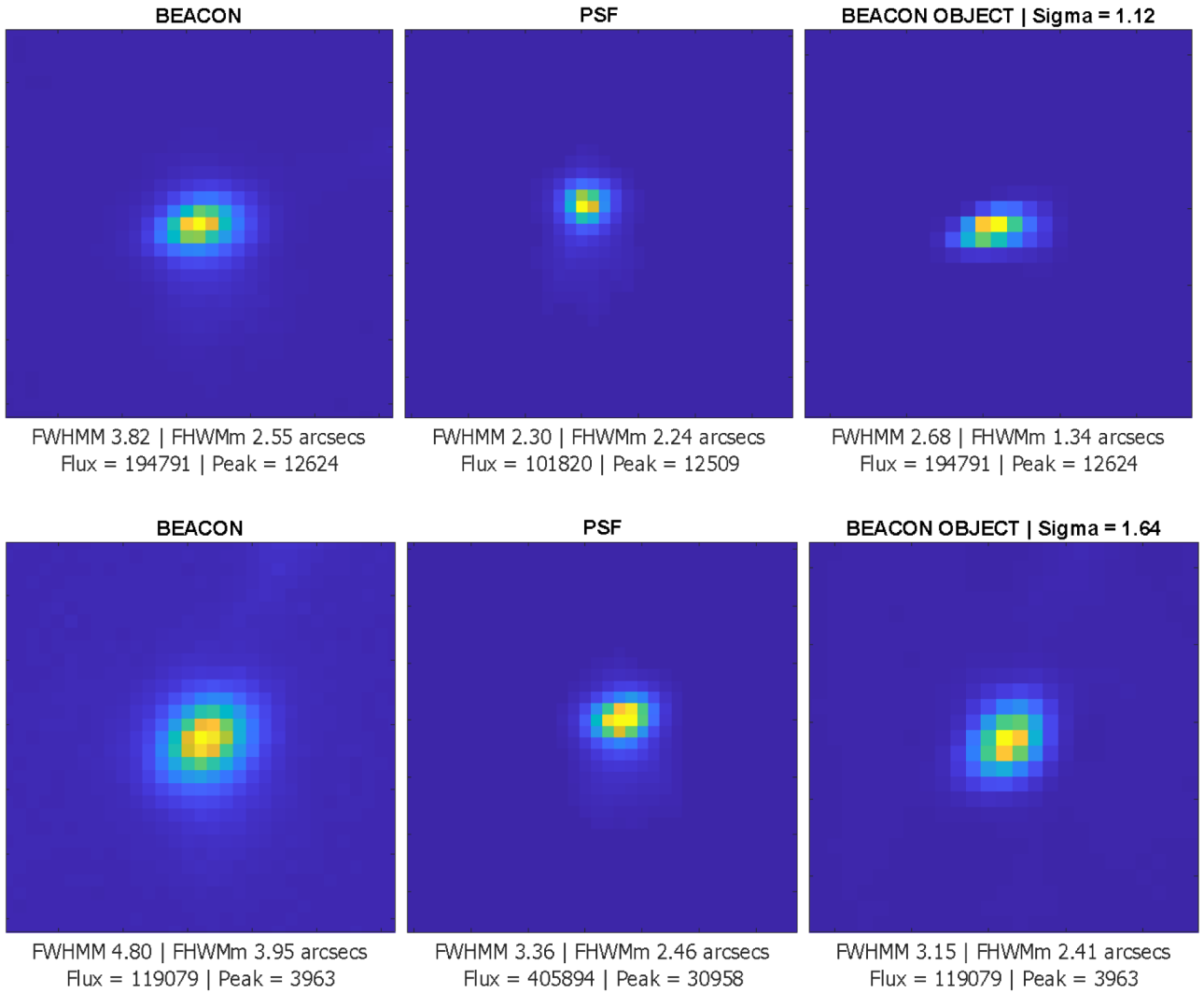
Results – Power scans

Power scans without repumping, double sideband, single sideband.





Results – LGS spot size



Conclusion

- Demonstrated observation of LGS return flux enhancement with chirping
- Identified optimal chirp rate near 0.6 MHz/μs
  - Correspond with I= 50 W/m^2 according to modeling
- No signs of saturation at higher power
  - Spot larger than expected, even in low seeing conditions (~0.6”)
- Better chirping efficiency in lower Na layers

Credits: Robert Johnson