Australian National University

Monitoring Mesospheric Sodium Layer for LGSAO by Continuous Laser Modulation Technique

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Problem : WFS Focus error

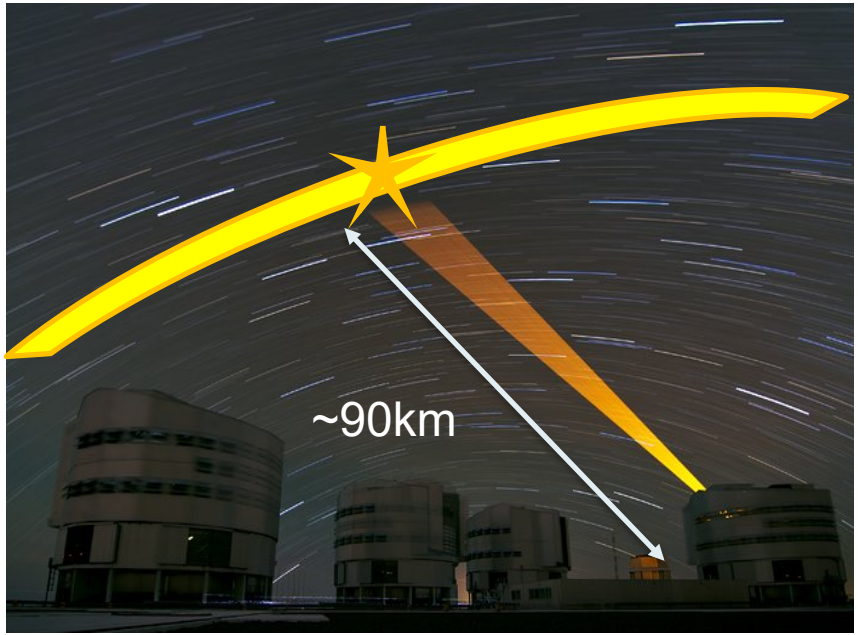


Image credits : ESO

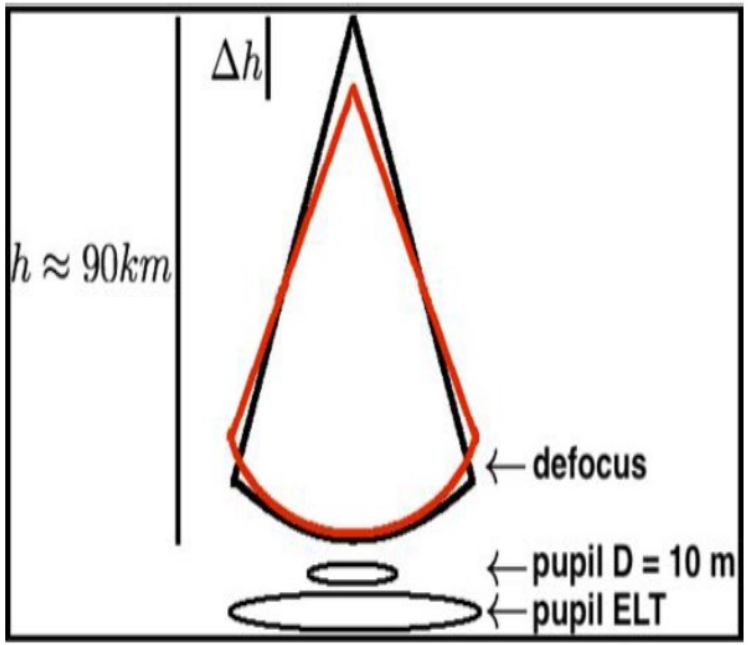
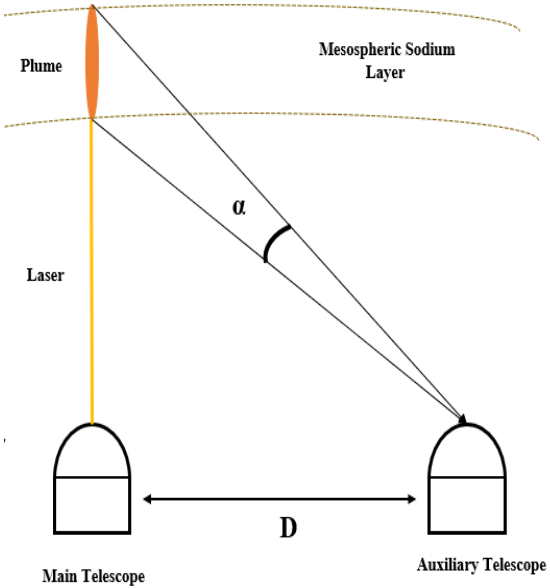


Image credits : Hickson,P.,& Ellerbroek,B.,et al., SPIE,2006

Current solutions: Monitoring Techniques

LIDAR

Image credits : Starfire Optical Range

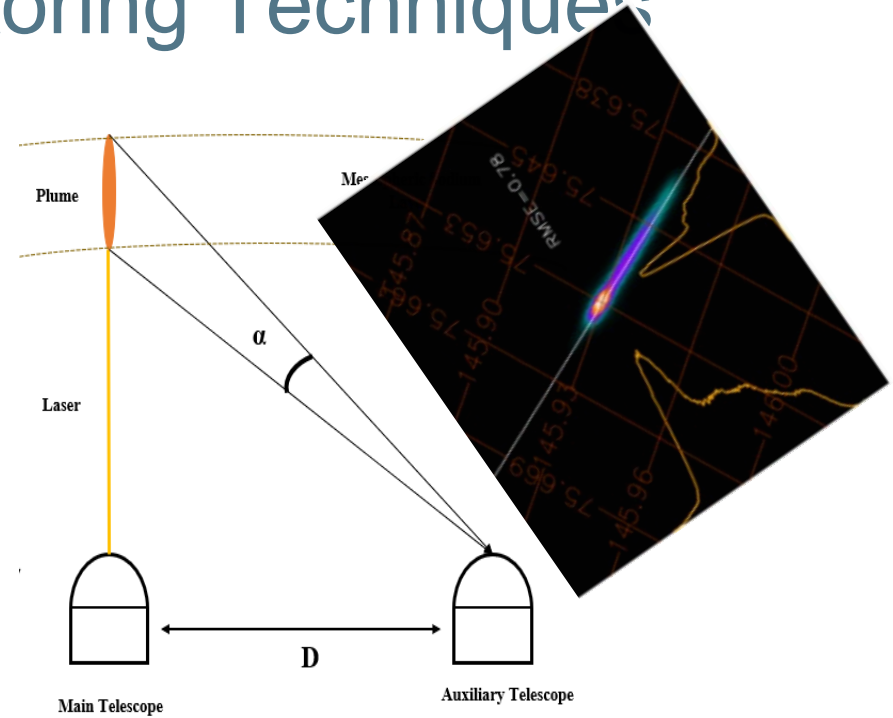


Direct imaging

Current solutions: Monitoring Techniques

LIDAR

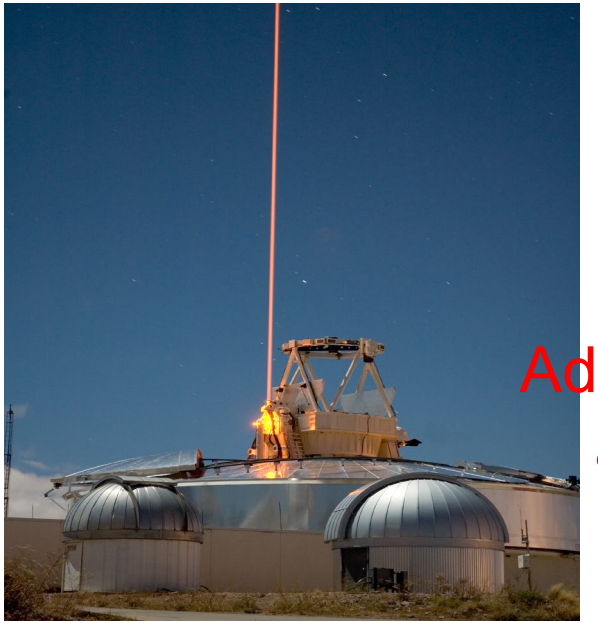
Image credits : Starfire Optical Range



Direct imaging

Image credits : Castro-Almazan & Alonso et al.,2016

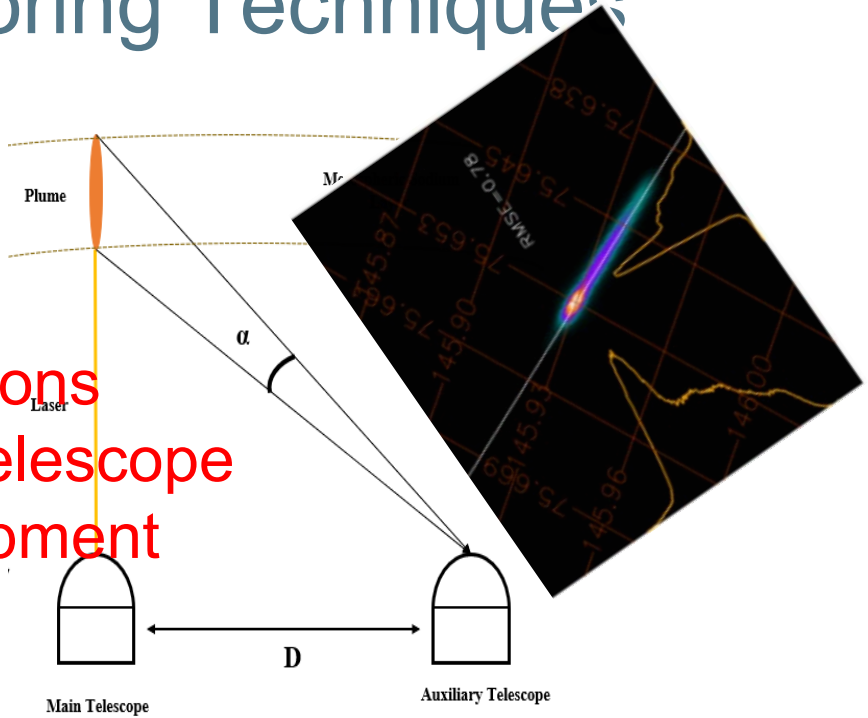
Current solutions: Monitoring Techniques



LIDAR

Image credits : Starfire Optical Range

Limitations
Additional telescope and equipment

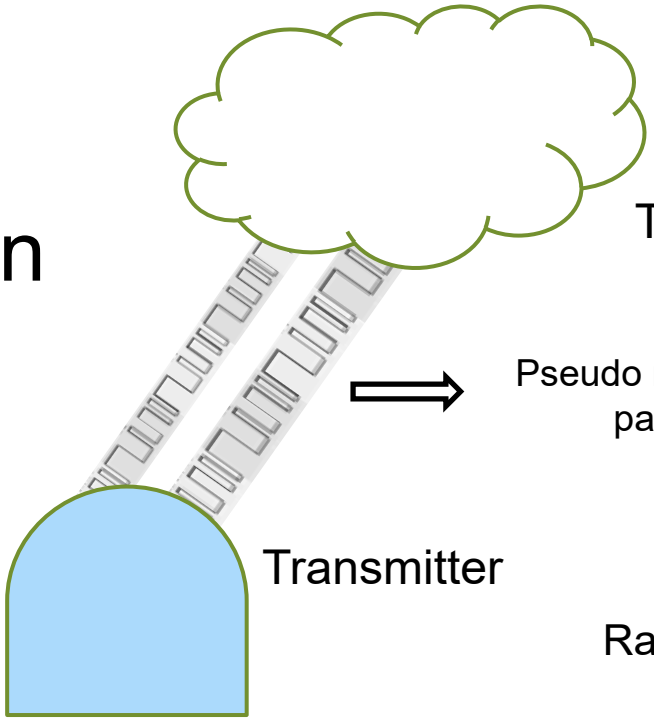


Direct imaging

Image credits : Castro-Almazan & Alonso et al.,2016

Any other solution?

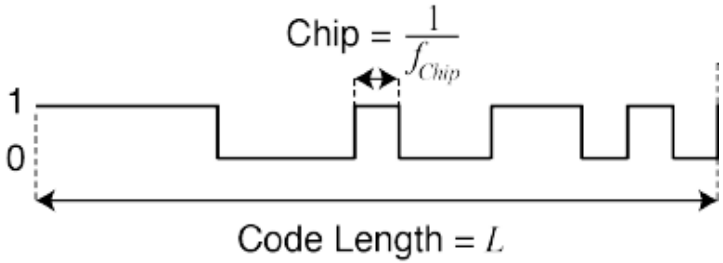
Laser modulation



Applications:

Ranging, Satellite communication etc.,

Pseudo Random Binary sequence



Length = 2^n-1 1's = 2^{n-1} 0's = 2^{n-1} -1

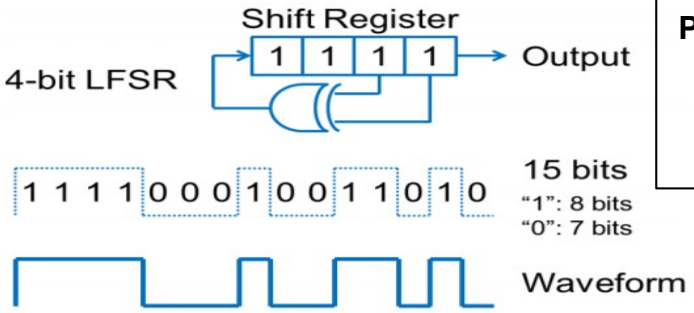
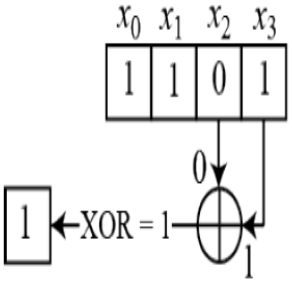
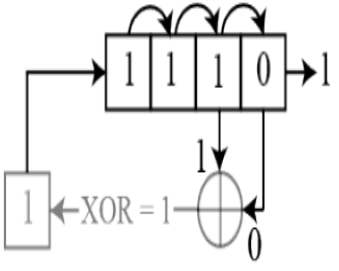


Image credits : Advantest

Polynomial co-efficient

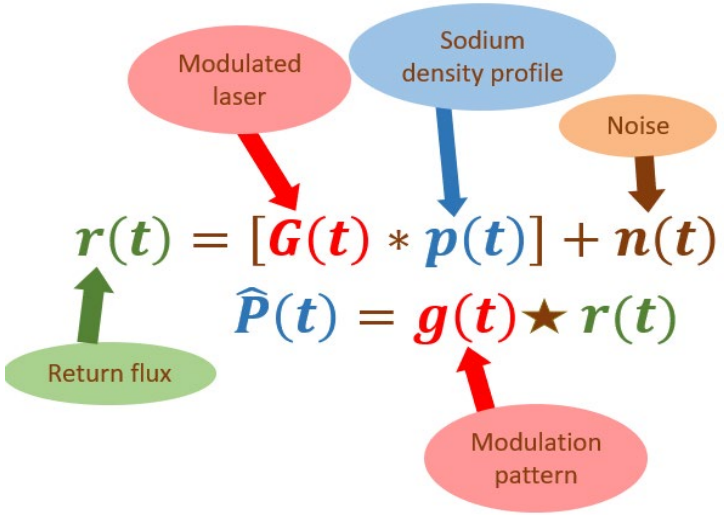
$$x^4 + x^3 + 1$$





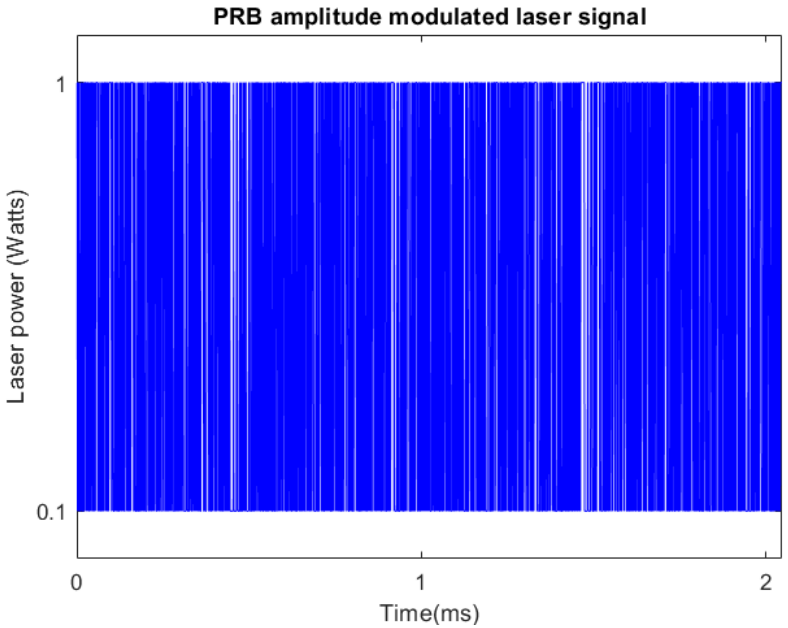
Application to LGS

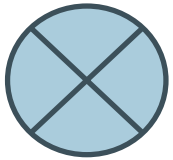
- Source: Laser
- Target: Sodium layer
- Modulation type: Amplitude
- Modulation pattern: maximum-length (M)sequence

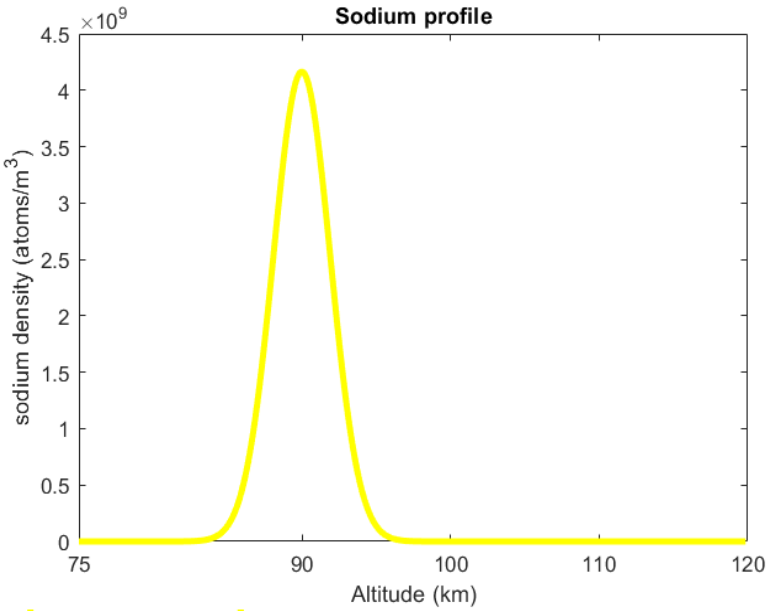


Reference : J.A.Hellemeier et al.,2018,Proc.SPIE 10703

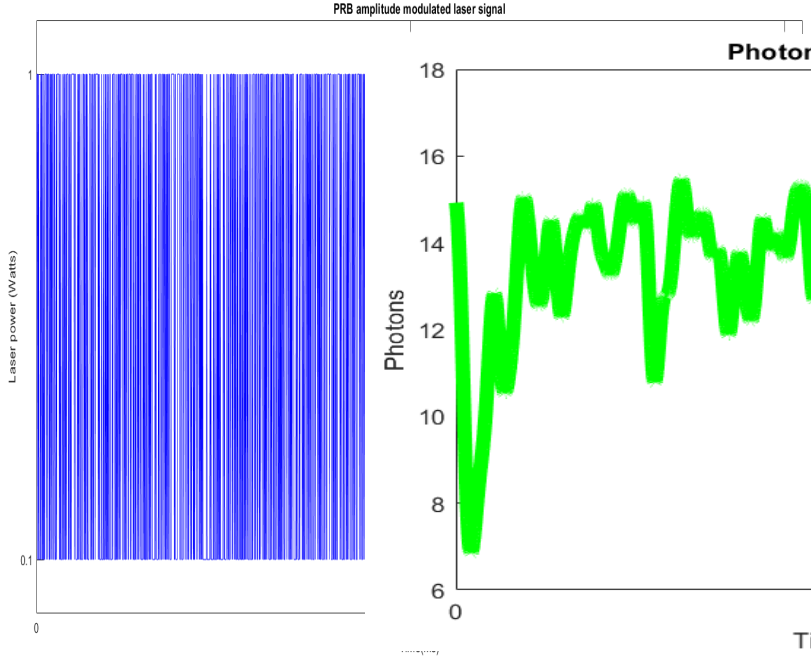
Implementation to LGS

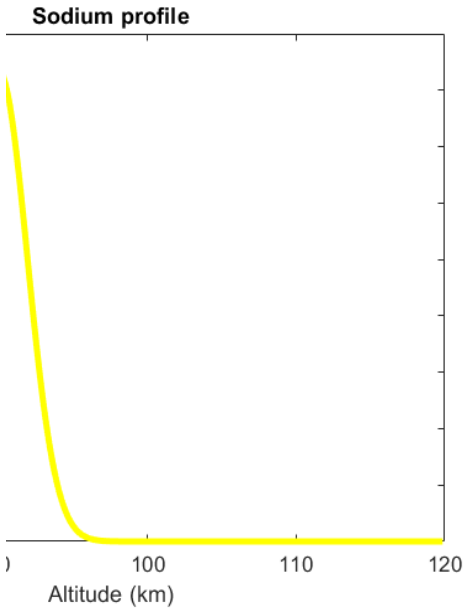


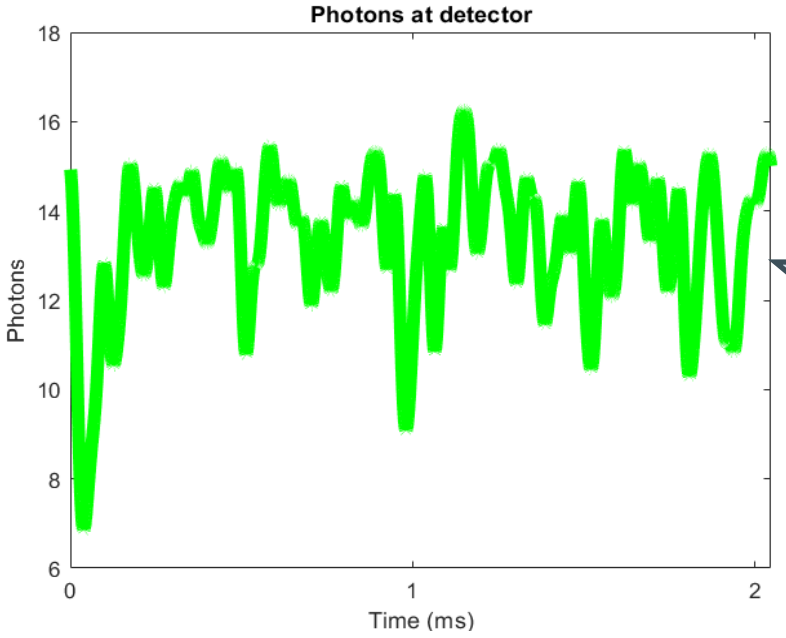


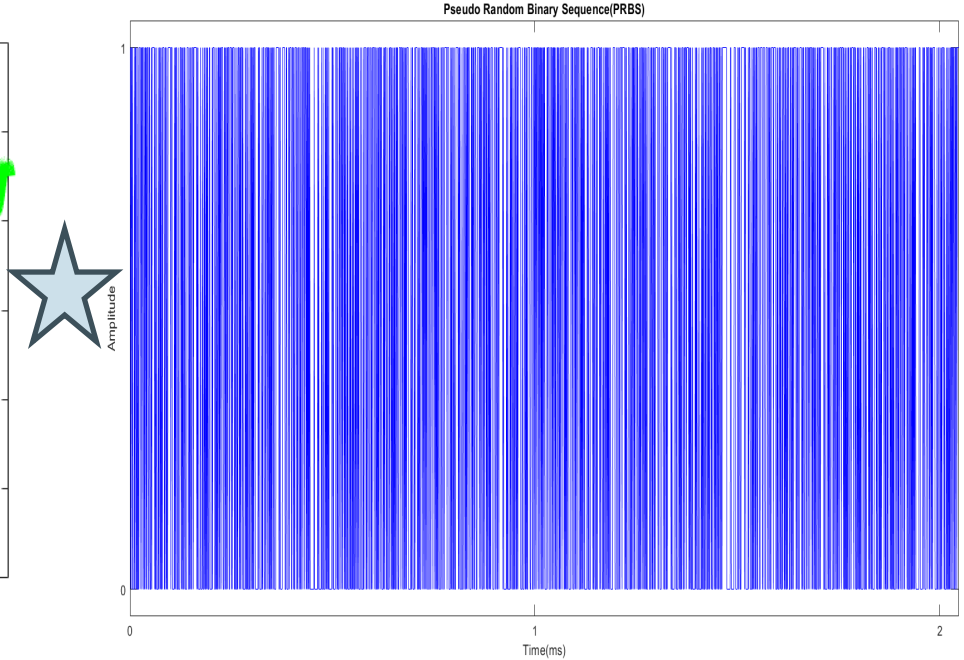


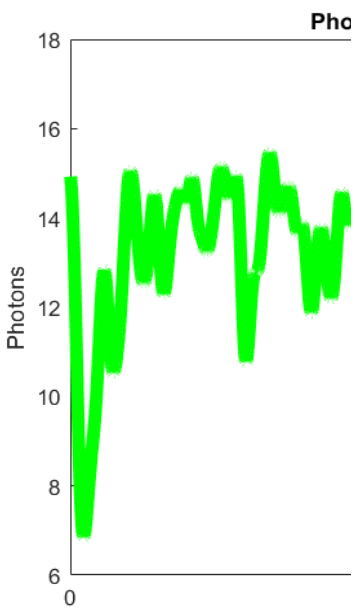
Implementation to LGS

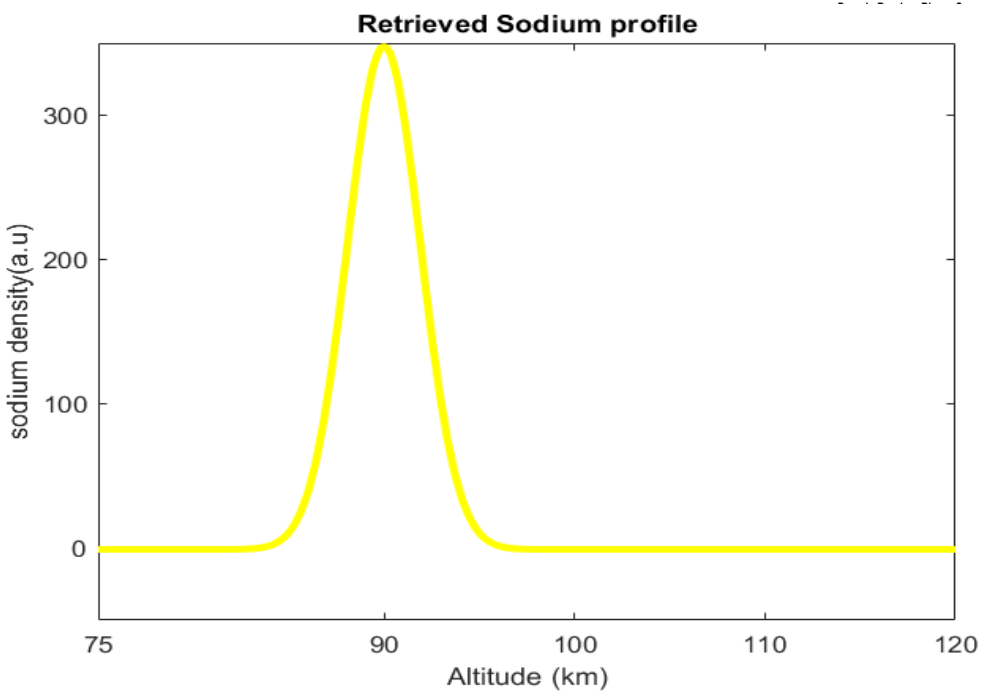


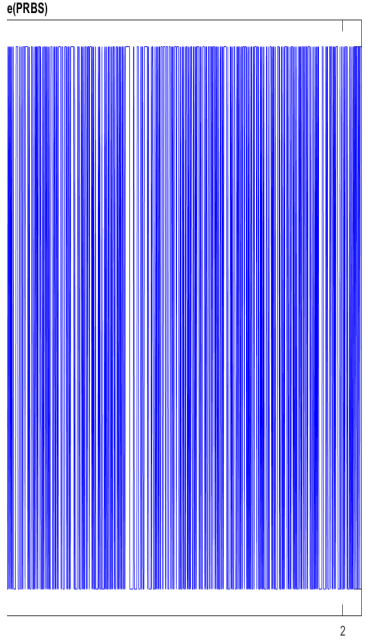



Photons at detector
Photons
Time (ms)
18
16
14
12
10
8
6
0
1
2


Pseudo Random Binary Sequence(PRBS)
Amplitude
Time(ms)
1
0
0
1
2


Pho
Photons
18
16
14
12
10
8
6
0


Retrieved Sodium profile
sodium density(a.u)
300
200
100
0
75
90
100
110
120
Altitude (km)


e(PRBS)
2

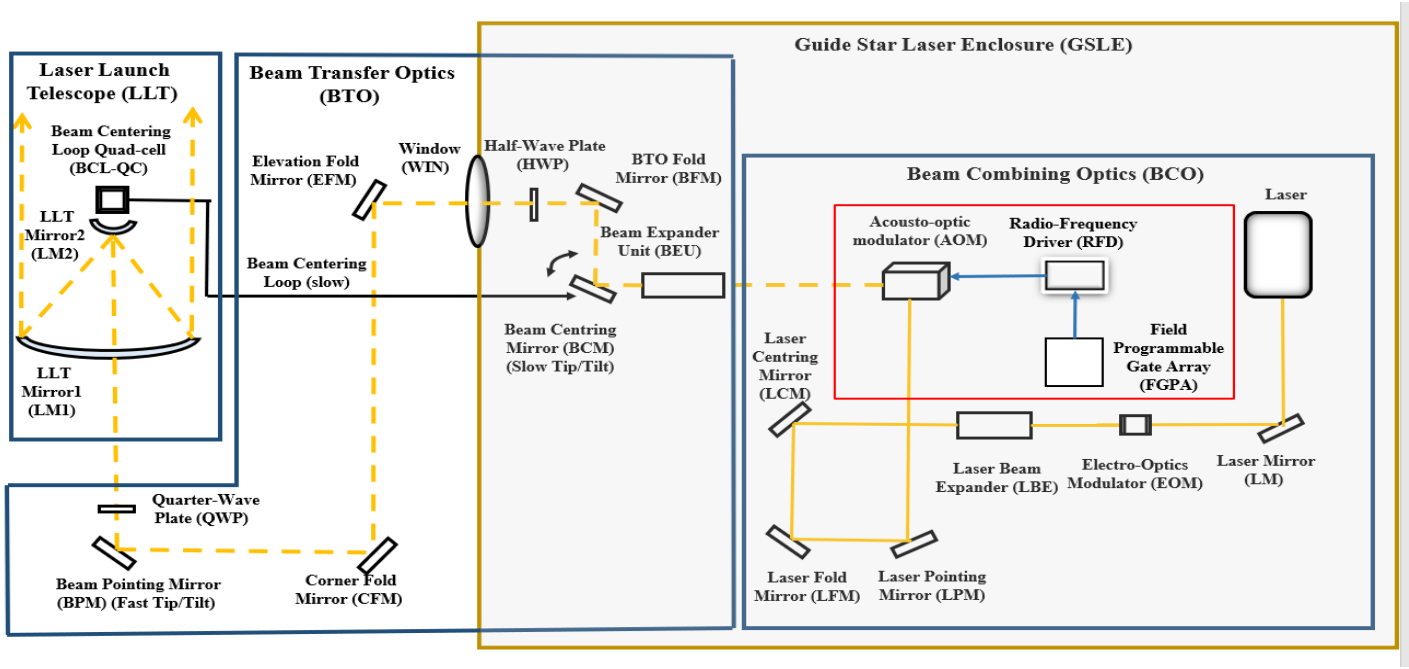
Previous test

Image credits : Calar Alto Telescope

Image credits : Large Zenith Telescope

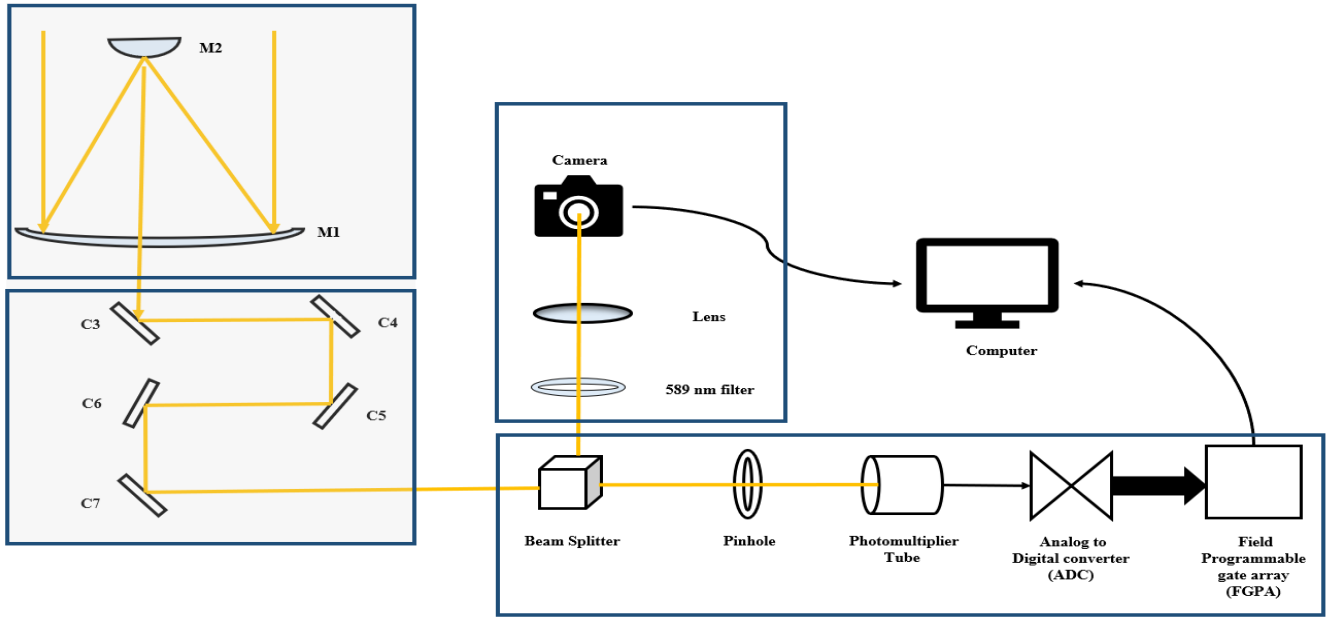
	Calar Alto Telescope	**Large Zenith Telescope**
Date of conduct	Oct 1999	July 2014
Spatial resolution	150 m	150 m
Limitations	Only 50% modulation was used. (D.J.Butler., R.I Davies., et.al A&A 403, 775–785 (2003))	Mismatch between simulated and experimental results as data was corrupted due to instrumental noise. (J.A.Hellemeier et al.,2018,Proc.SPIE 10703)

Laser modulation and transmitter



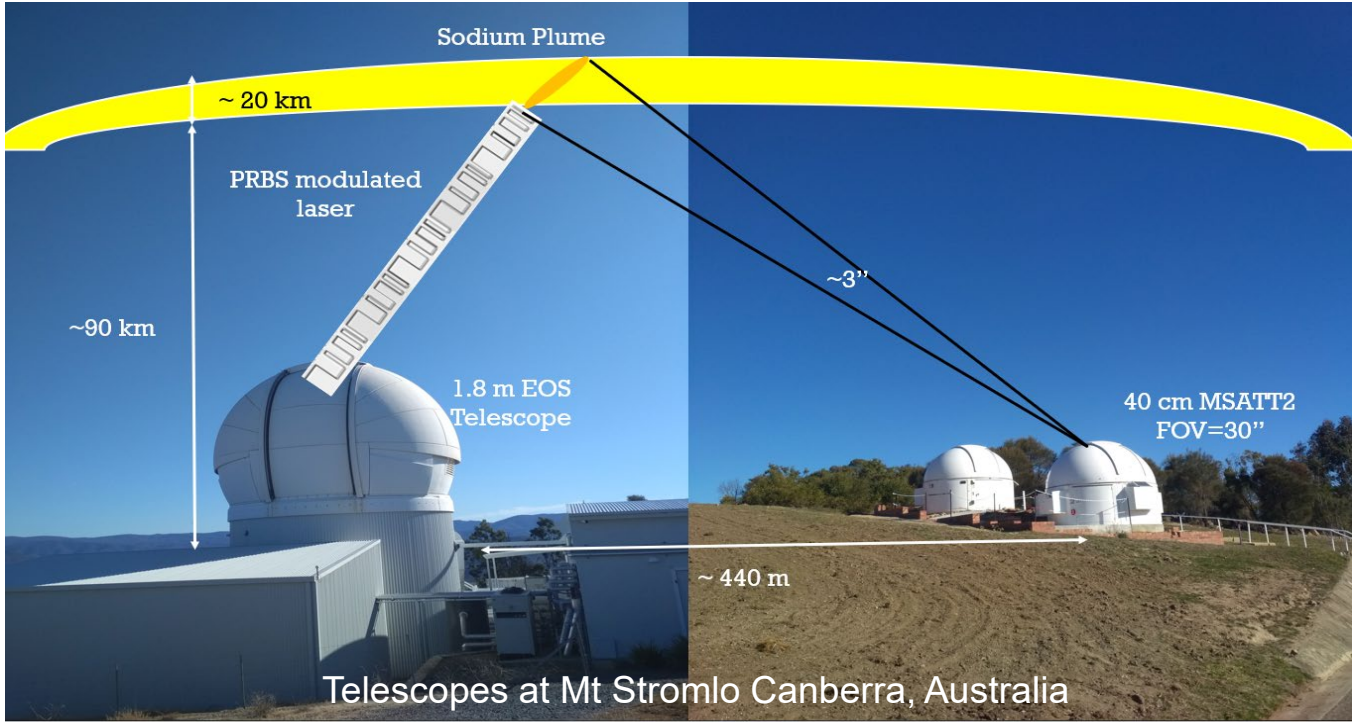
Laser Guidestar Facility at 1.8m EOS telescope, Mt Stromlo Canberra, Australia

Receiver and processing



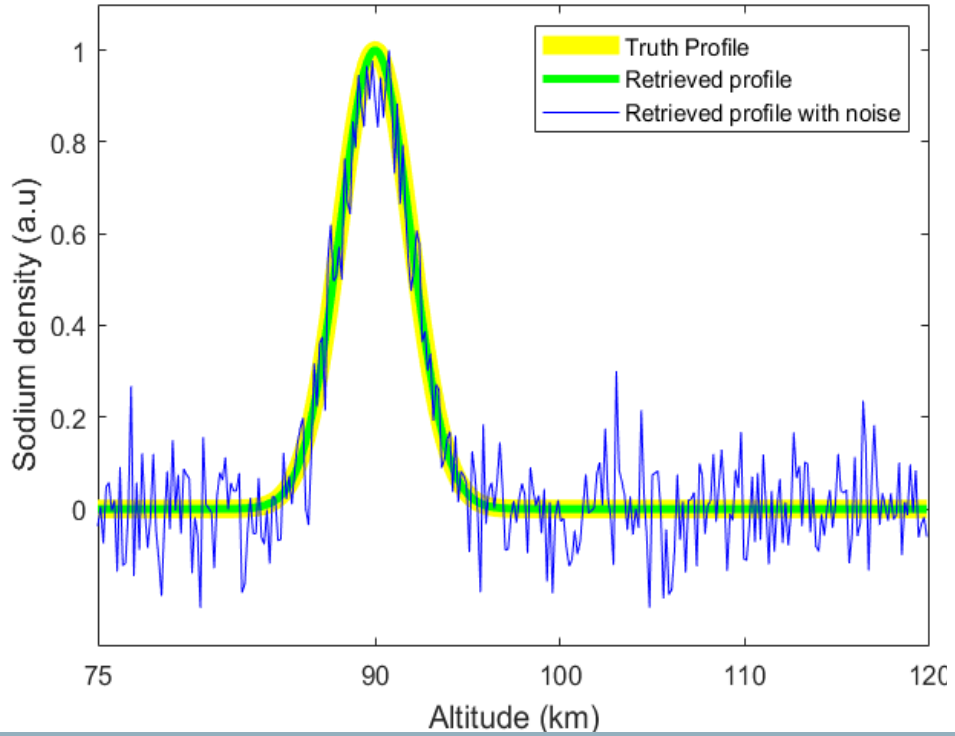
Test bench in Coudé lab at 1.8m EOS telescope, Mt Stromlo Canberra, Australia

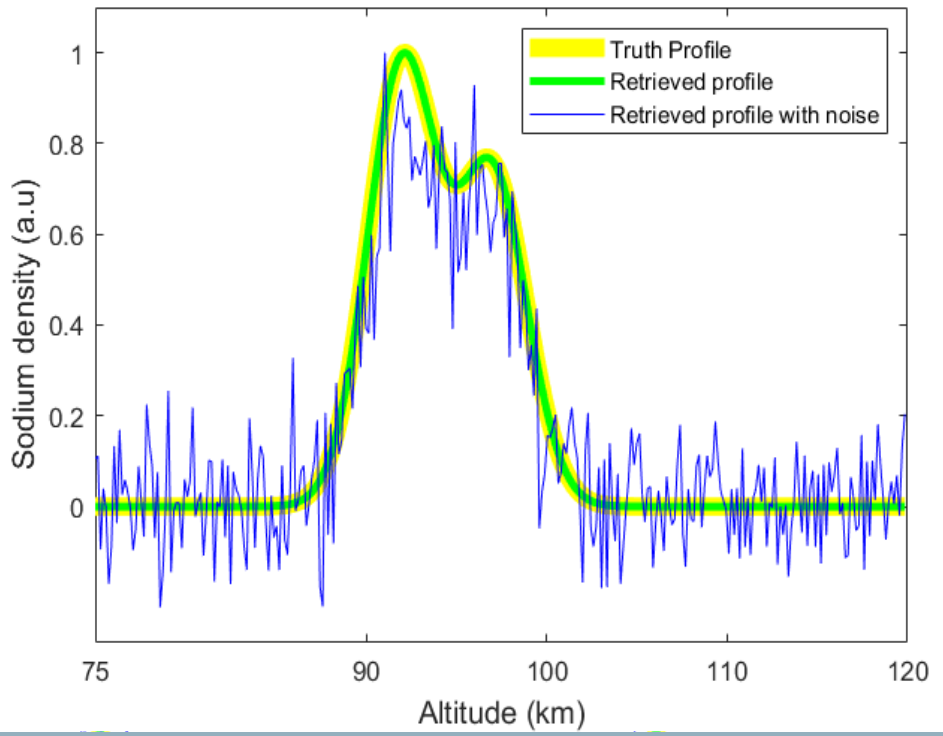
Validation



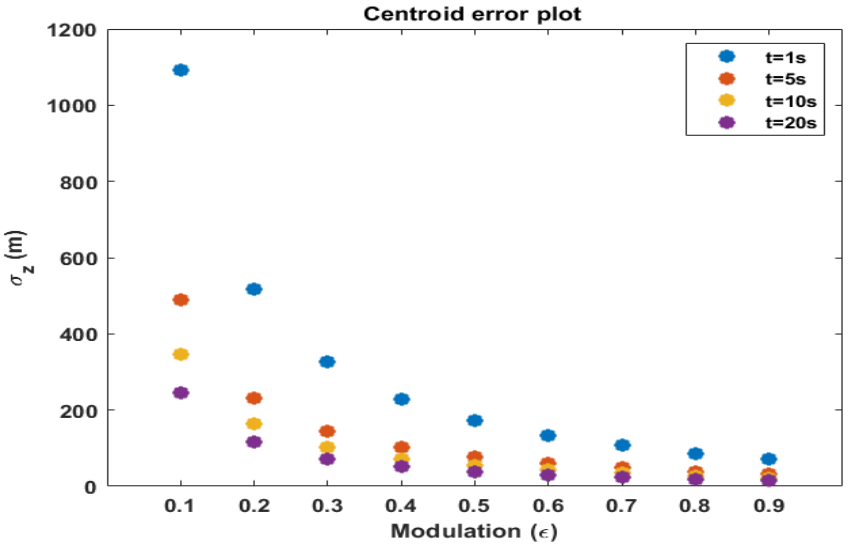
Telescopes at Mt Stromlo Canberra, Australia

Retrieved sodium profiles



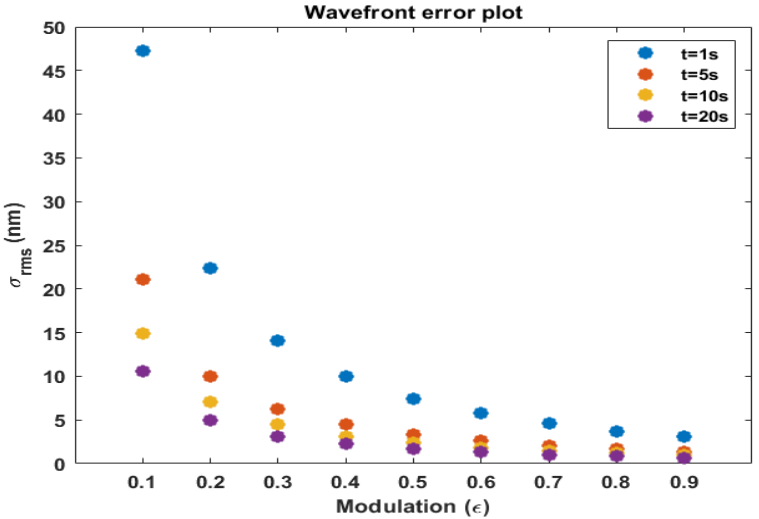


Predicted errors



$$\sigma_z \simeq \frac{2-\epsilon}{\epsilon}\sqrt{\frac{n}{12N_\gamma}}Z \qquad N_\gamma = N_0(1-\epsilon/2).$$

N_0=Flux at primary mirror = 6.5 M photons/m^2/s ,
Laser power=20W, Column density=2E13 atoms/ m^2



$$\sigma_{rms} = \frac{1}{16\sqrt{3}}\frac{D^2}{\bar{z}^2}\sigma_{\bar{z}},$$

Reference : J.A.Hellemeier et al.,2020

Future work

- Find the rms centroid error from simulation.
- Conduct experiment and retrieve sodium profile.
- Verify experimental results with theoretical and simulation results.
- Carry out “Sodium monitoring campaign” from Q2 2021.

Conclusion

- Implementation and testing of successful laser modulation technique.
- Previous test didn’t produce results for different laser modulation depth and mismatch in simulation and experimental results
- Profiles of resolutions 60 m and higher is expected to be produced from this project.
- The first ever“ Sodium monitoring campaign ” for LGS in Australia will contribute to statistical database.

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