

Research outline

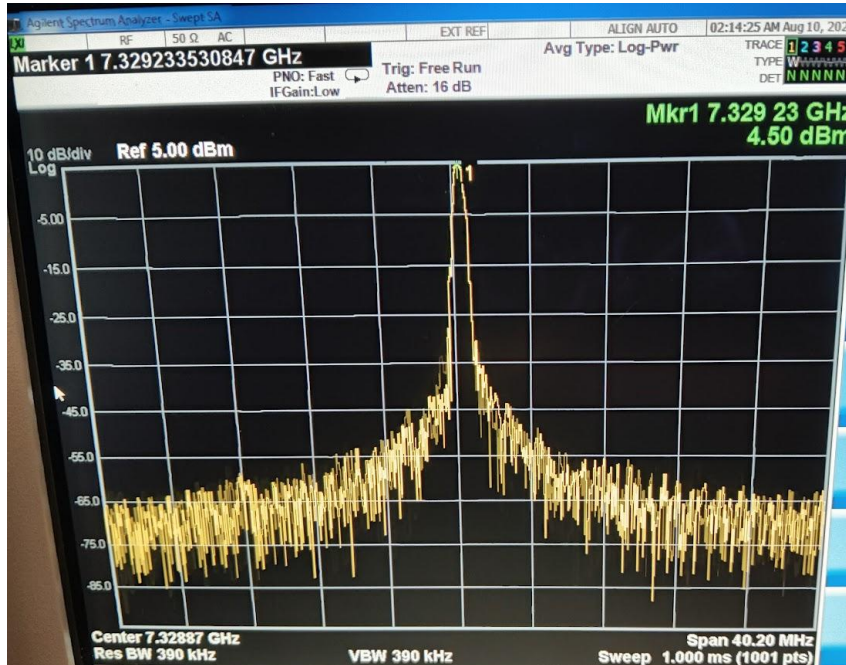
Krishna Balaji S

Summer 2024: Rydberg Array Quantum Simulation Lab

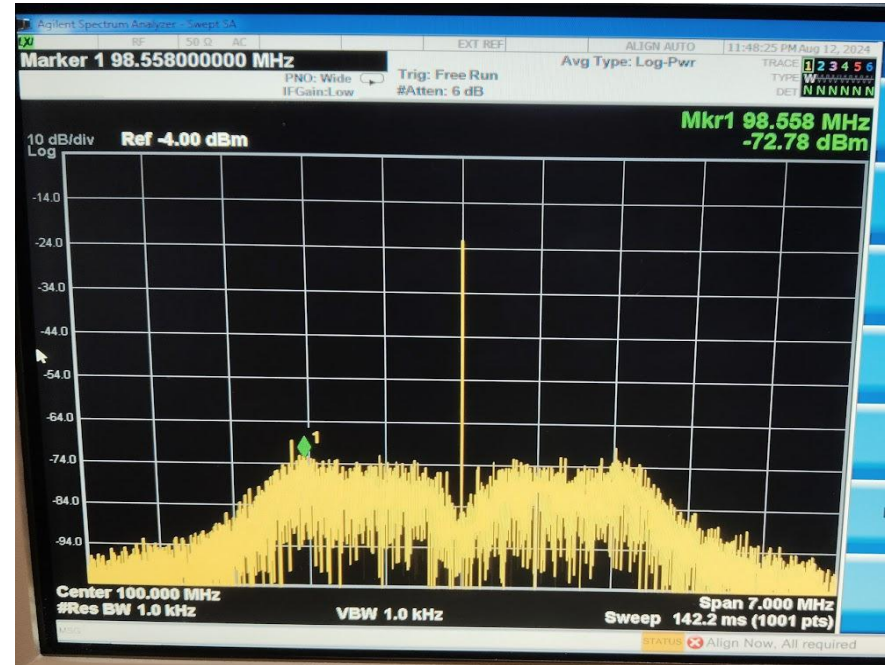
Institute for Quantum Computing, Waterloo

Summer 2024 - IQC Waterloo

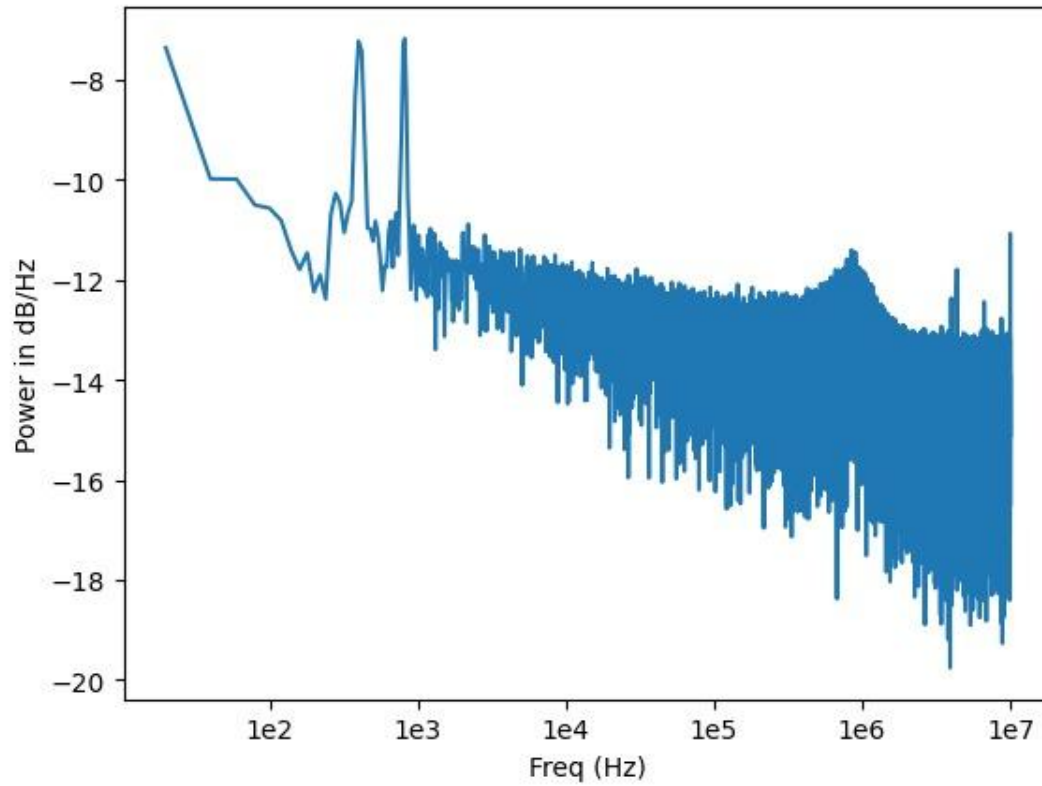
1. Locking the Raman Lasers at 6.83GHz using Optical PLL



Optical Beat signal (Pre-Lock)



Optical Beat signal (Post-Lock)

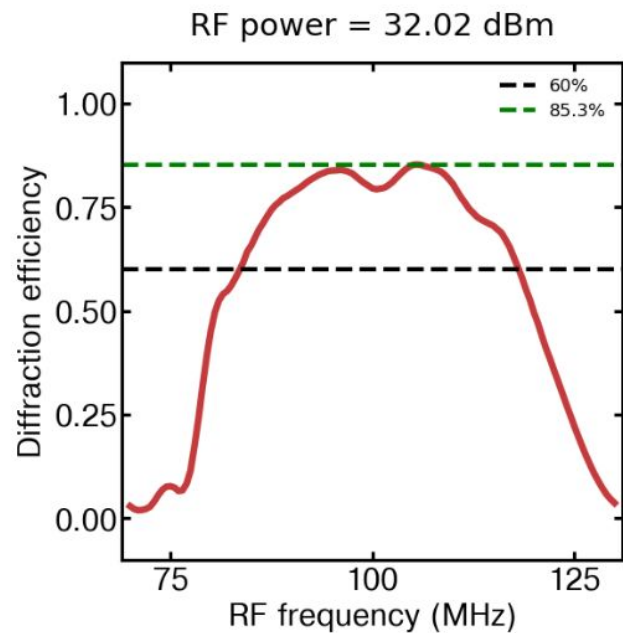


Phase Noise spectrum (reveals vibrational sources in the lab)

2. Generating Raman tweezer arrays



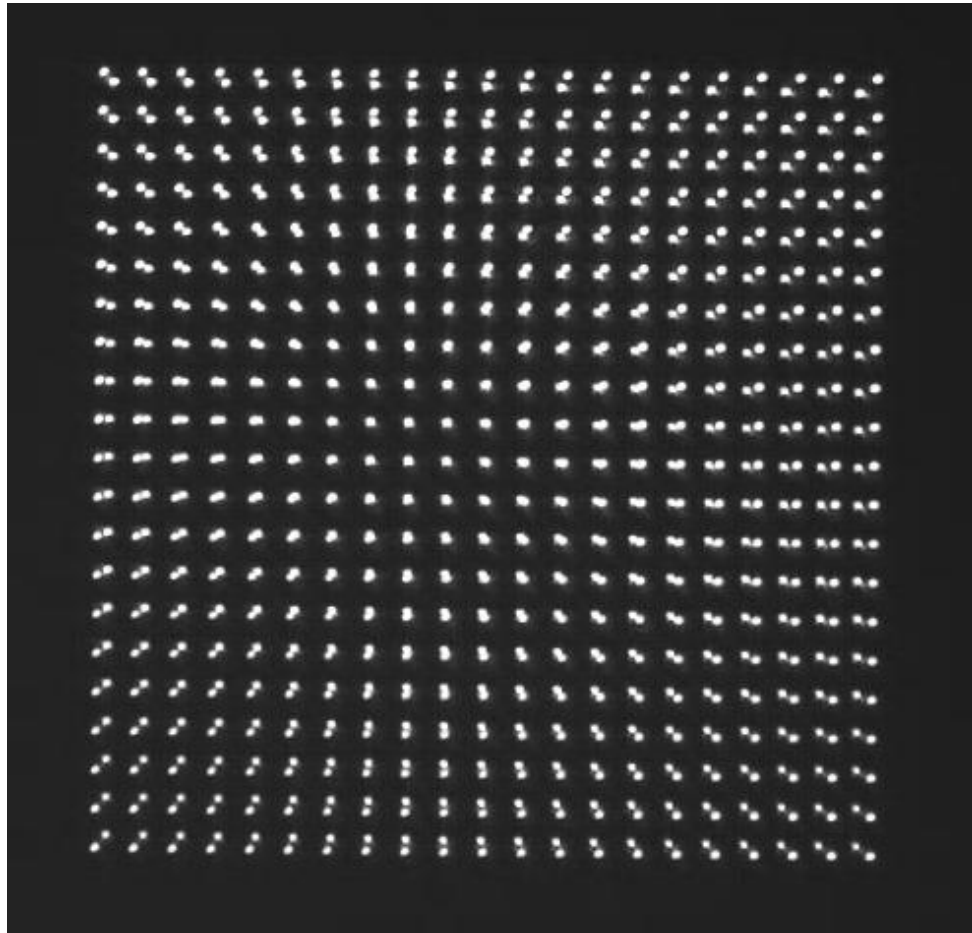
Aligned the array with respect to laboratory reference using a real-time Python script.



AOD Diffraction efficiency curve

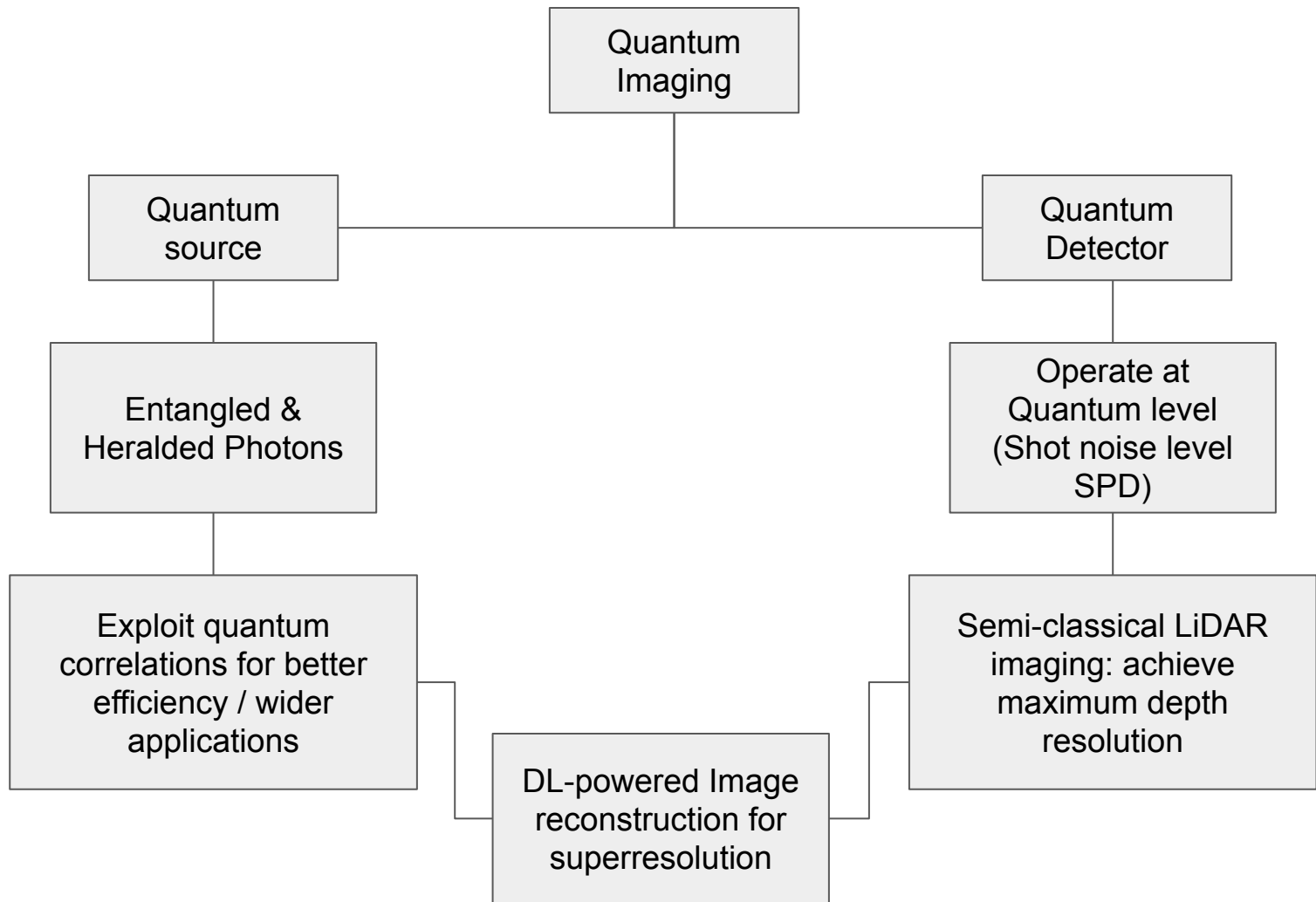
Final result:

- Lasers phase-locked at 6.83GHz.
- 1/2 inch board set up to co-propagate the beams (necessary for Λ -Raman transition) and stabilize intensity.
- 2D AODs setup near the main experiment to operate in site-selective configuration.



Final Traps (tweezer and Raman)(credit - Soroush)

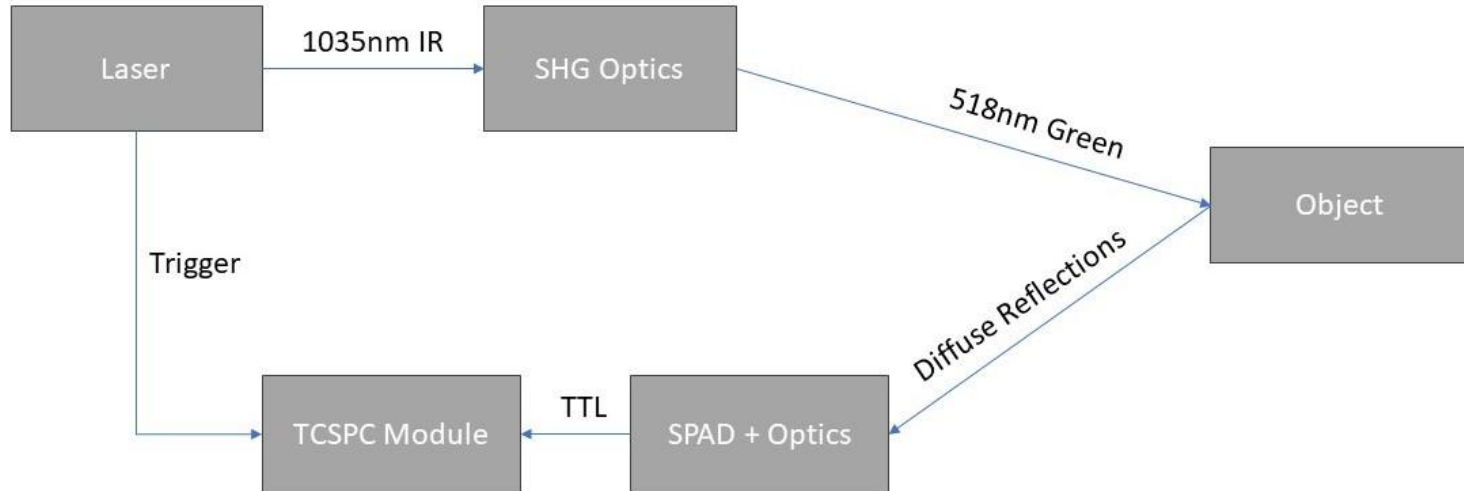
Quantum Imaging @ IITM



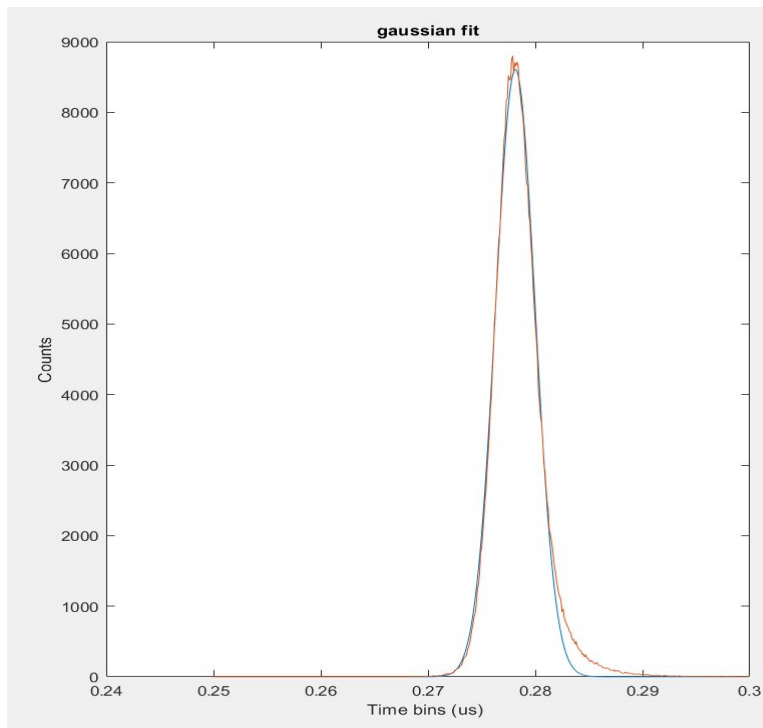
Single-Photon LiDAR Imaging:

- Femtosecond Laser pulses illuminate the scene
- Collect pulse arrival times with respect to a source reference
- Construct a histogram of pulse arrival times

Setup Schematic

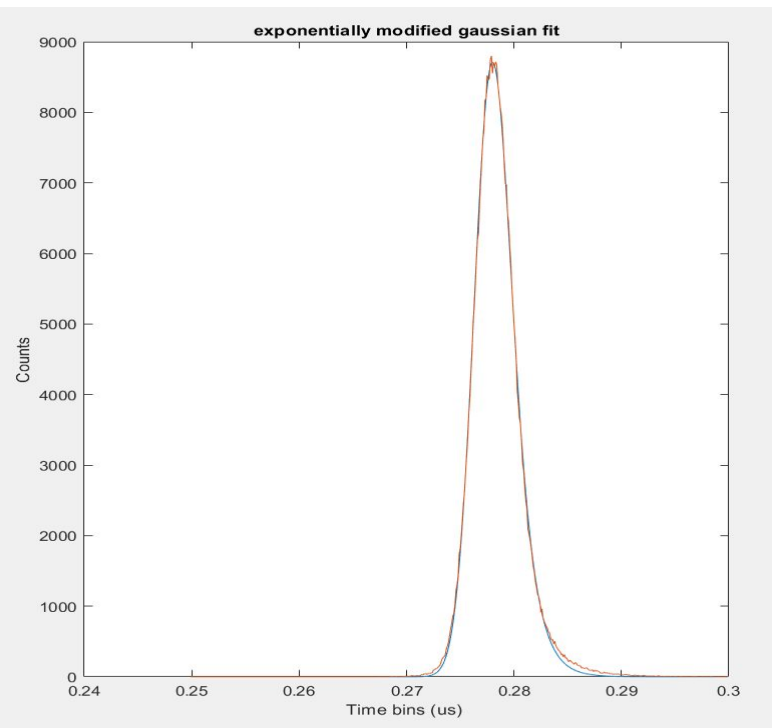


Comparing Histogram fits:



$$f(x) = a \exp\left(-\frac{(x-b)^2}{2c^2}\right)$$

(Gaussian)



$$f(x; \mu, \sigma, \lambda) = \frac{\lambda}{2} e^{\frac{\lambda}{2}(2\mu + \lambda\sigma^2 - 2x)} \operatorname{erfc}\left(\frac{\mu + \lambda\sigma^2 - x}{\sqrt{2}\sigma}\right)$$

(Exponentially modified Gaussian)

Limitations and Next steps:

- Analytical estimation doesn't work well in presence of excess background light

To tackle this, we are exploring two approaches:

- Multi-step denoising (use reflectivity, depth correlations in scene)
- Deep-learning based estimation (inspired from Sensor-fusion)

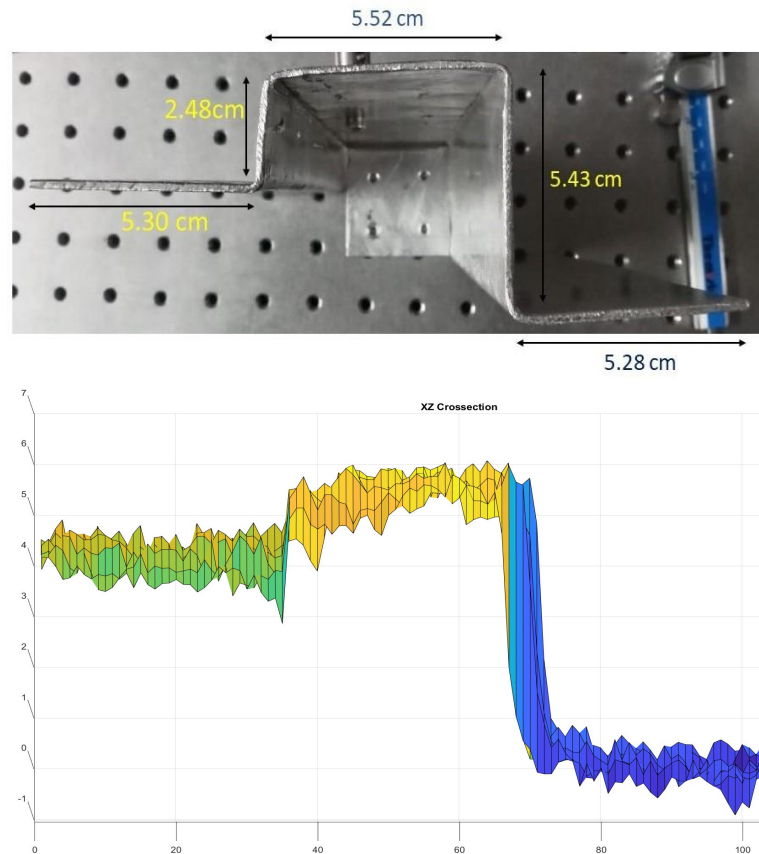


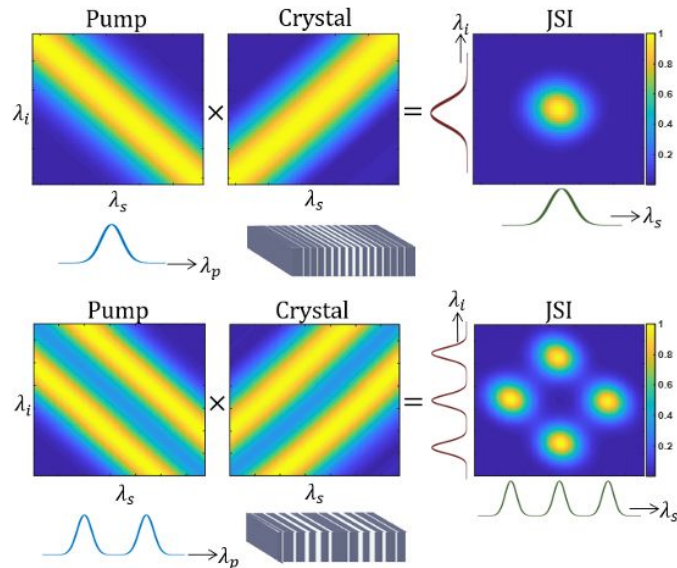
Figure: Reconstructed LiDAR image (RMSE: 9mm)

Present: Optical GKP states for Quantum Error correction

(September 2024 -)

Quasi-Phase matching using PPKPT

- By tuning $\chi(2)$ as a function of z , we can control the Phase Matching Function (PMF)
- Achieved using discrete optimization.

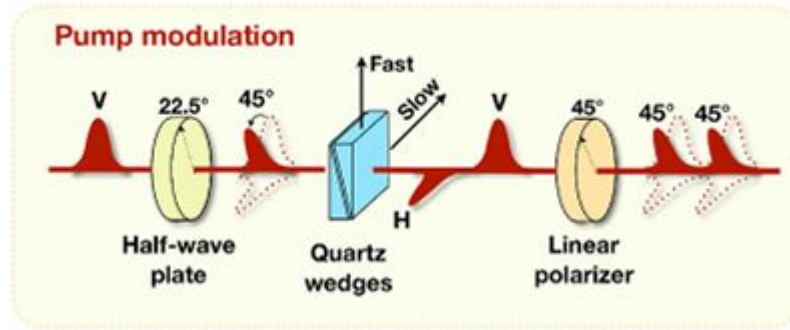


Ref: Ady et al, 2020

Fig. 1. Illustration of the 2-dimensional control over the JSI. Top - Gaussian-shaped pump spectrum and PMF resulting a round JSI. Bottom - double-Gaussian-shaped pump spectrum and PMF resulting a 4 lobe JSI.

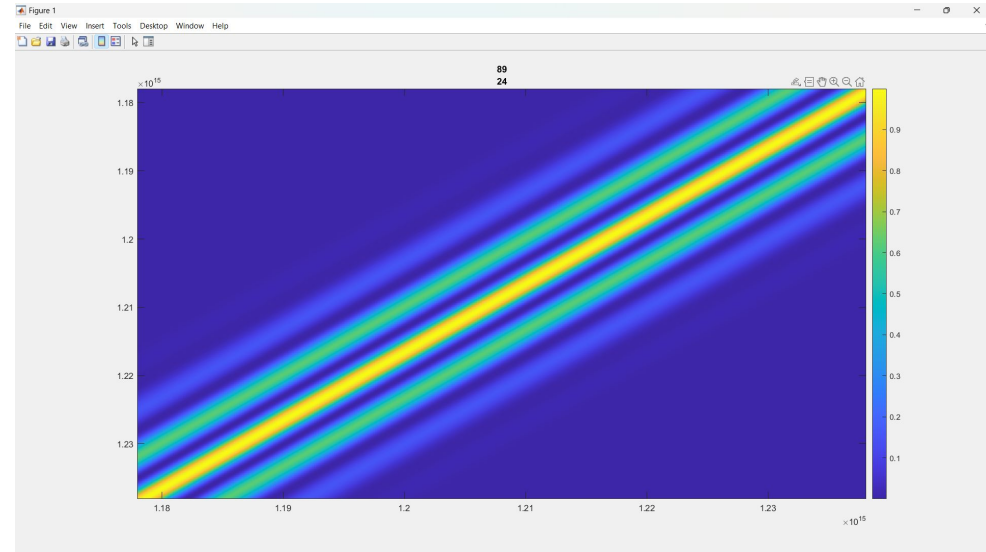
Quasi-Phase matching using PPKPT

- It is possible to modulate both Pump spectrum and PMF to achieve a require JSI at the output.



Ref: Ady 2020

We are aiming to use these two degrees of freedom to generate time-frequency GKP state.



Complex pump modulation to achieve higher order Hermite-Gaussian modes. (results from MATLAB simulation)