Research outline

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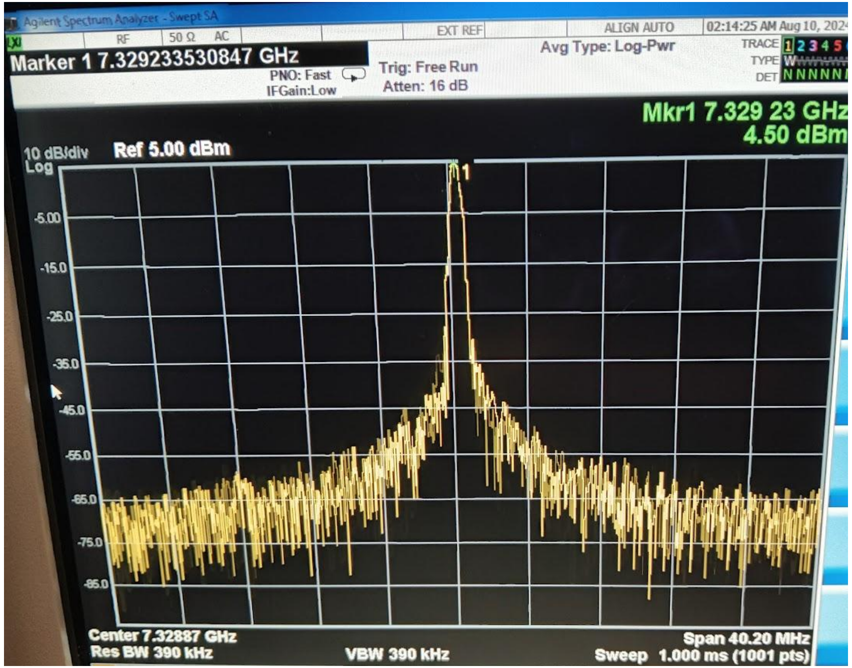
Summer 2024: Rydberg Array Quantum Simulation Lab

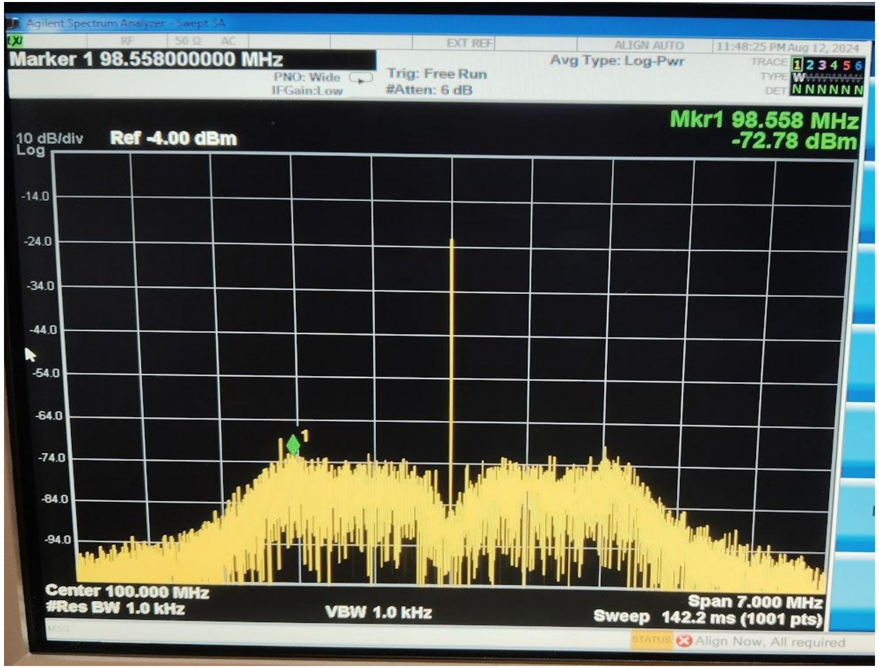
Institute for Quantum Computing, Waterloo

Summer 2024 - IQC Waterloo

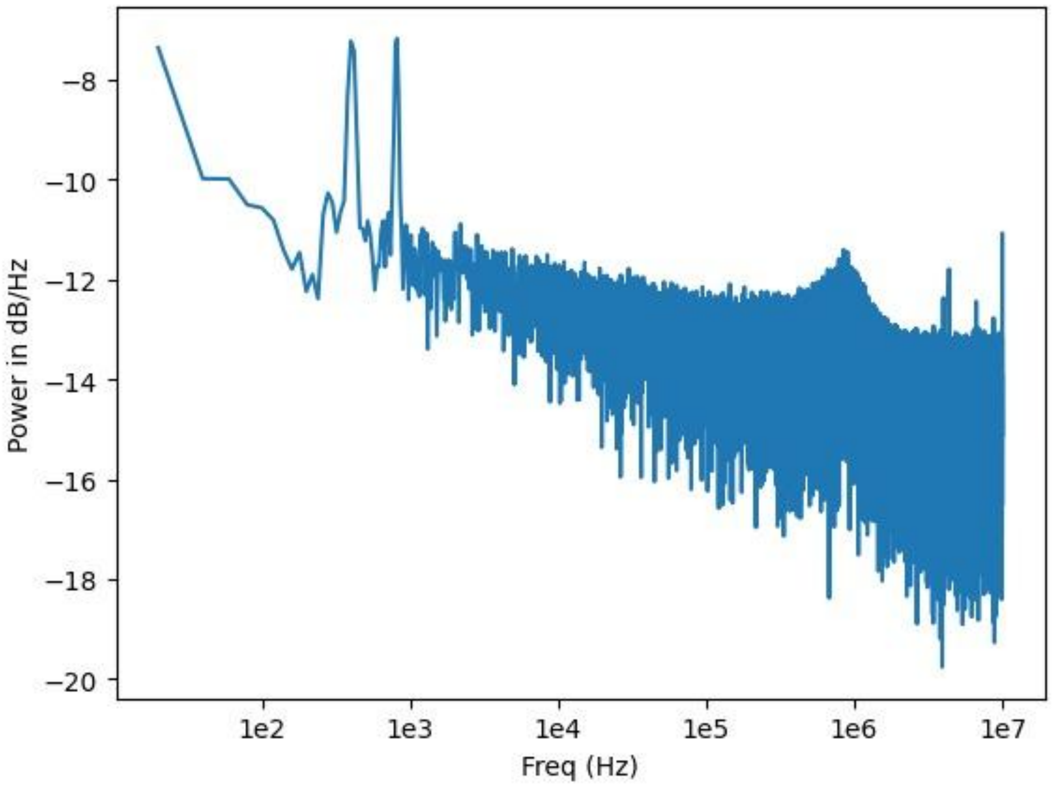
1. Locking the Raman Lasers at 6.83GHz using Optical PLL



Optical Beat signal (Pre-Lock)



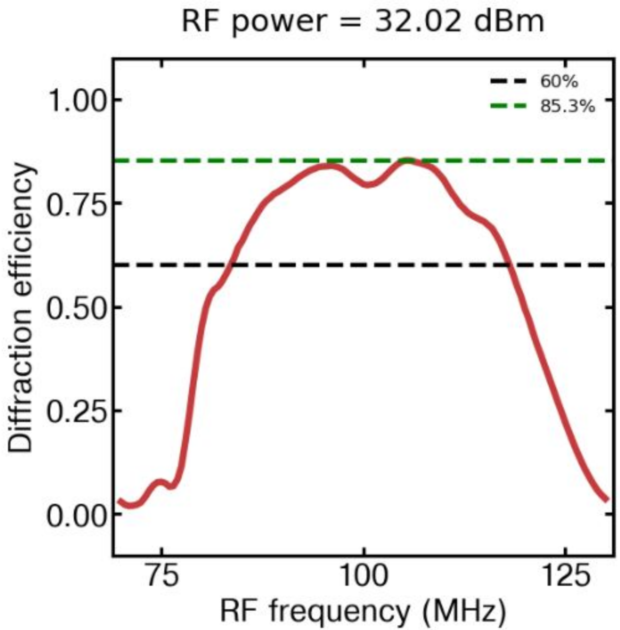
Optical Beat signal (Post-Lock)



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.



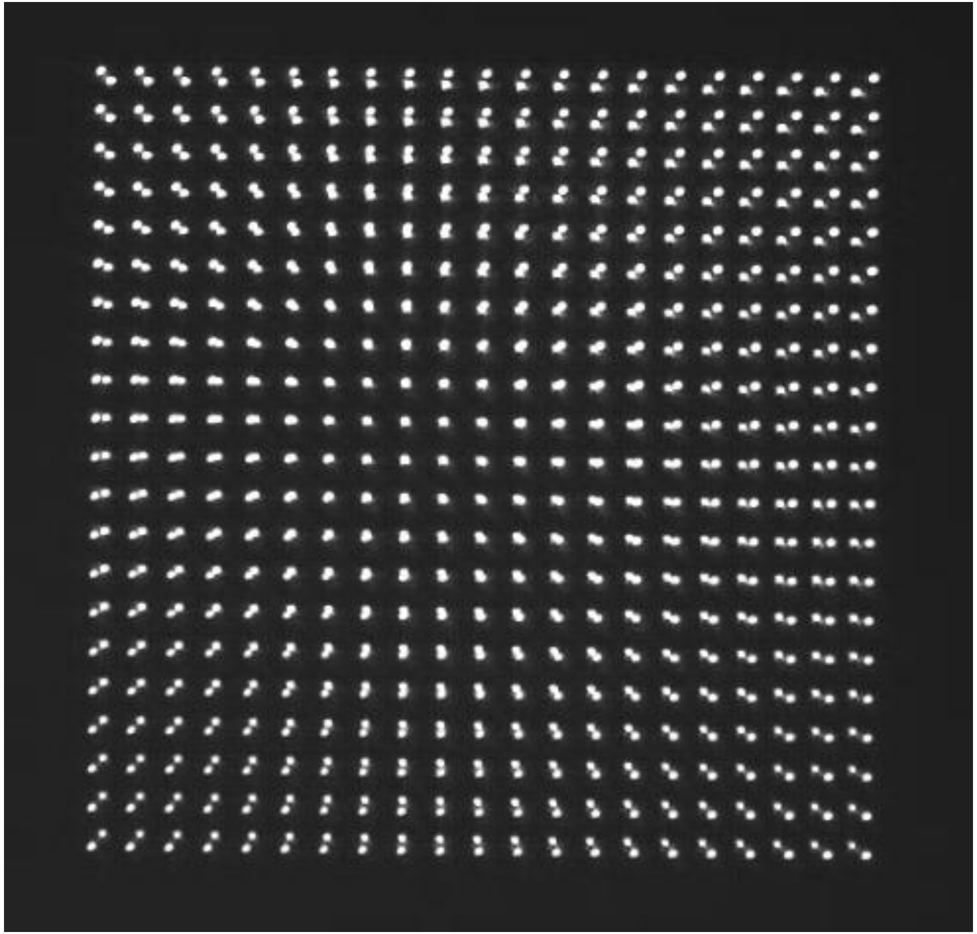
AOD Diffraction efficiency curve

Final result:

- Lasers phase-locked at 6.83GHz.

- ½ 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)

Summer 2023: Radio Astronomy Lab

Raman Research Institute, Bangalore

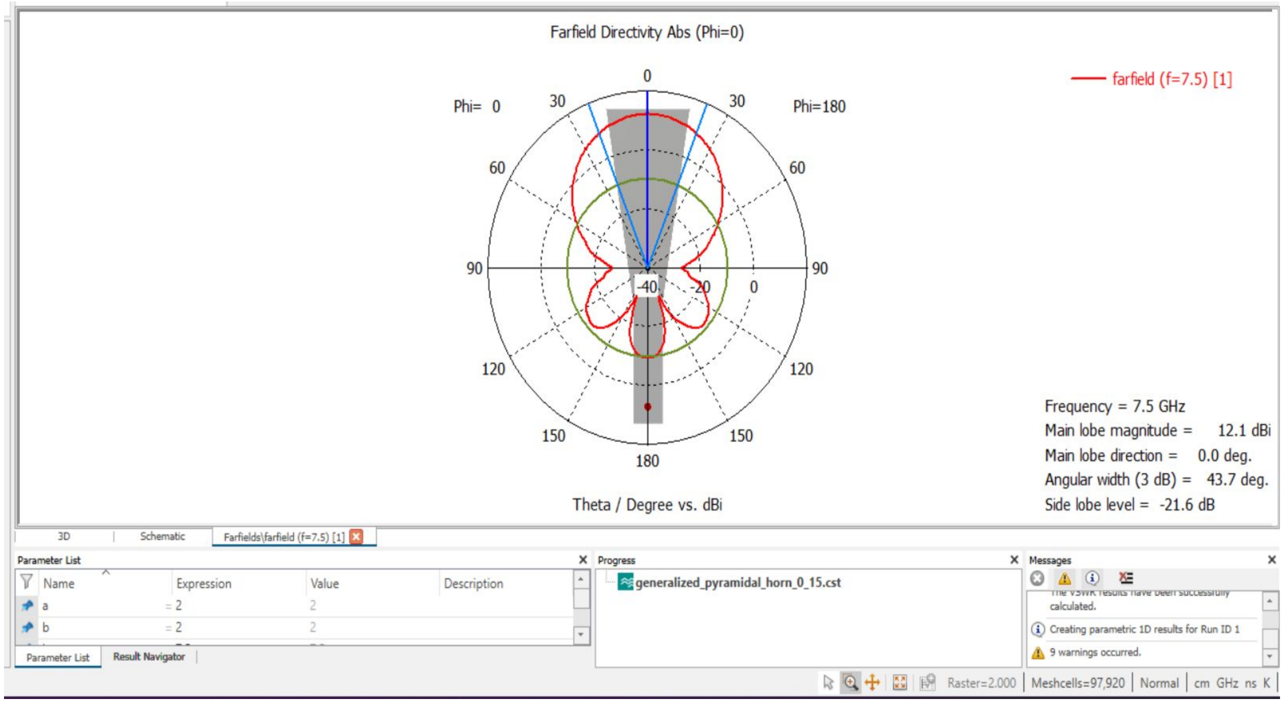
CST Microwave - Antenna Simulations

Fairfield results for a Generalized horn

At 7.5GHz

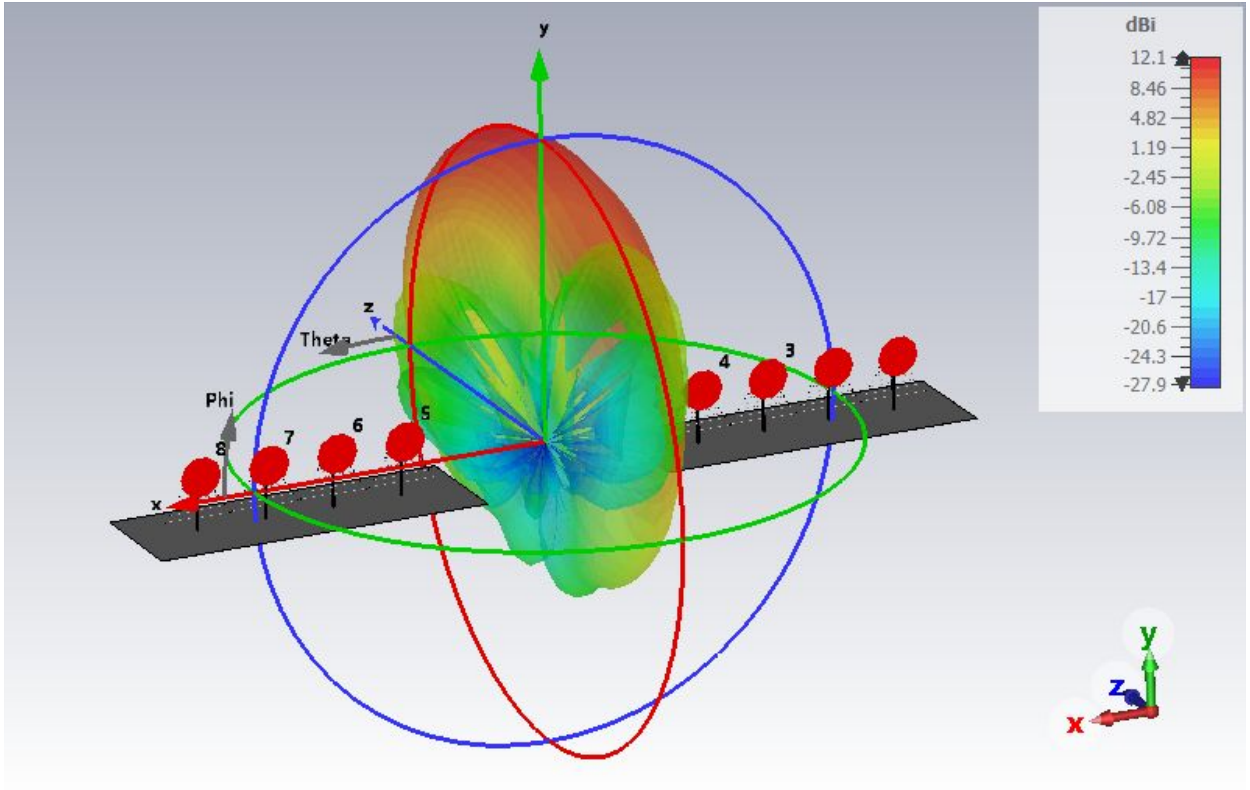
Optimized performed for a general frequency range

(in my case, 1 to 10 GHz)



LPDA Response simulated (pic credit: Likhit)

- “Phased Array” dipole antennas
- Response simulated by Likhit in CST



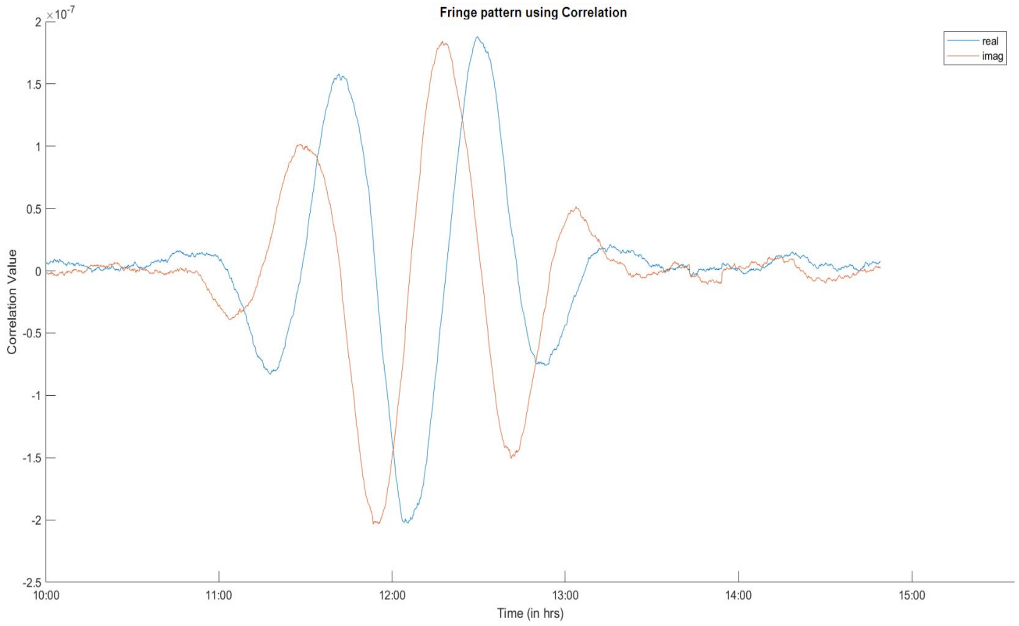
Beamwidth calculation

Simulated beamwidth:

20.0 deg

Observed beamwidth:

~22.5 deg beamwidth

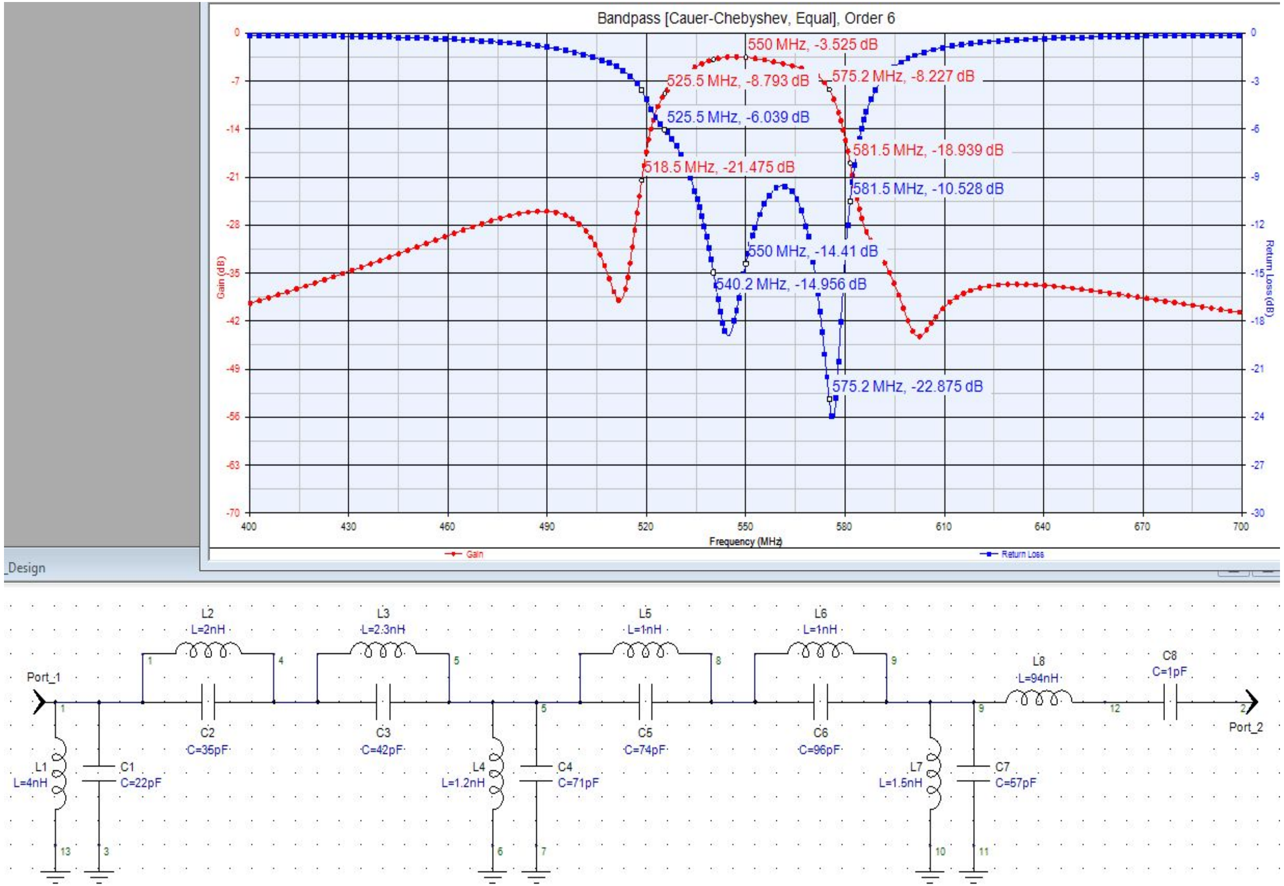


Correlation fringes from Phased array LPDA

Filter design

IF filter for Superhet receiver

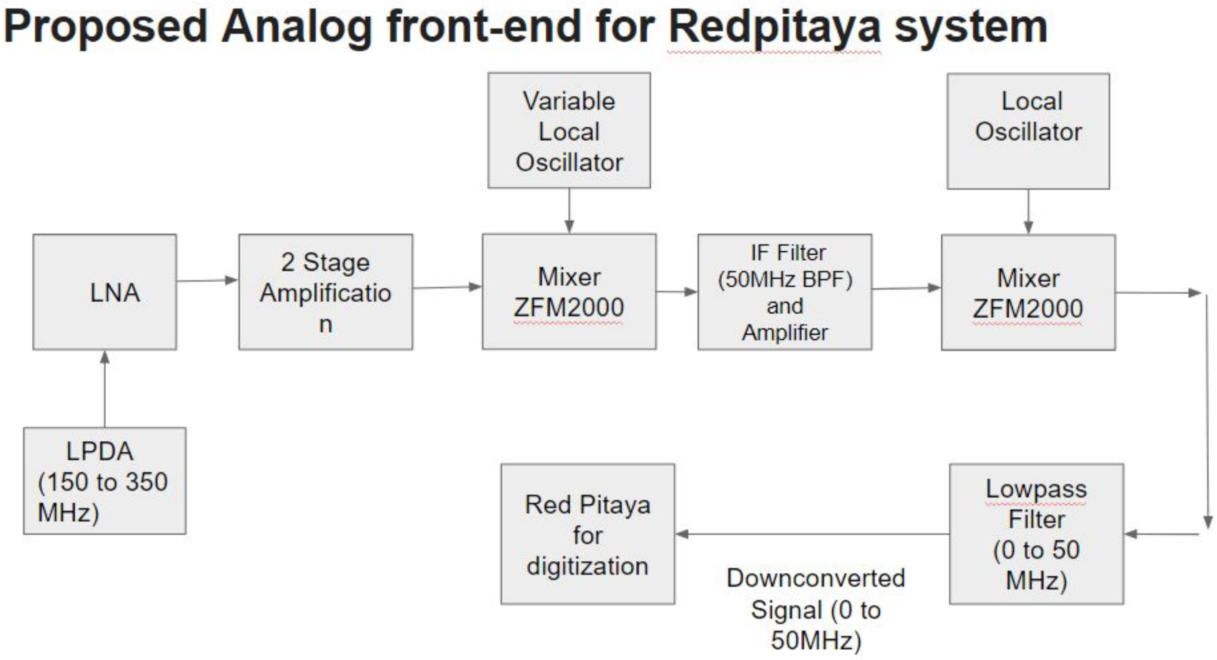
(Keysight Genesys)



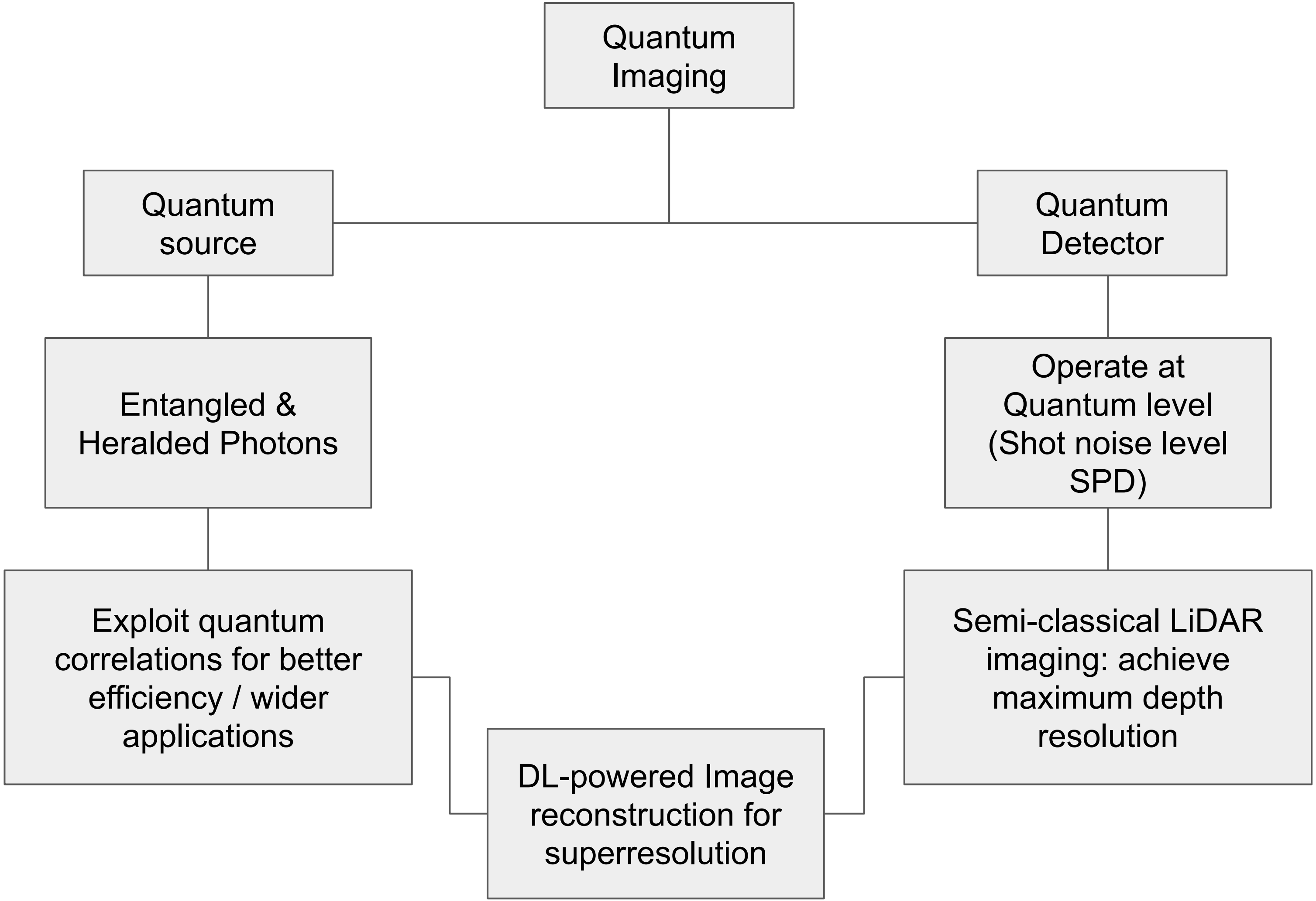
In essence:

- Developed a tunable filter to scan across 150 to 350 MHz

- Enabled high speed acq (125Msps 8 bit data) link



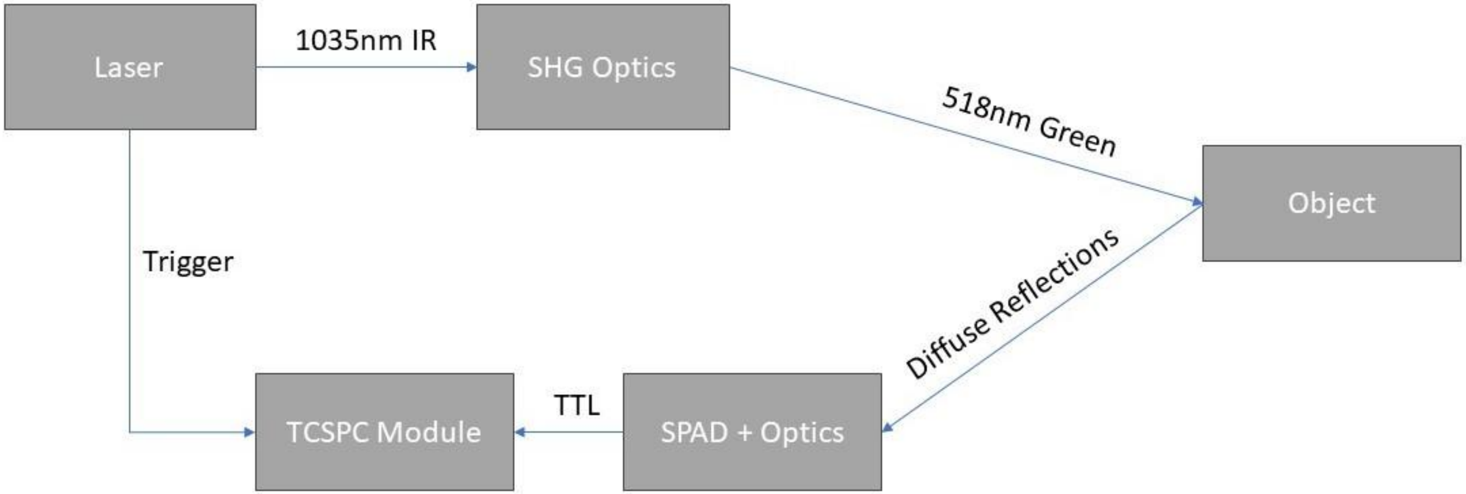
Quantum Imaging
@ IITM


Quantum Imaging
Quantum source
Quantum Detector
Entangled & Heralded Photons
Operate at Quantum level (Shot noise level SPD)
Exploit quantum correlations for better efficiency / wider applications
Semi-classical LiDAR imaging: achieve maximum depth resolution
DL-powered Image reconstruction for superresolution

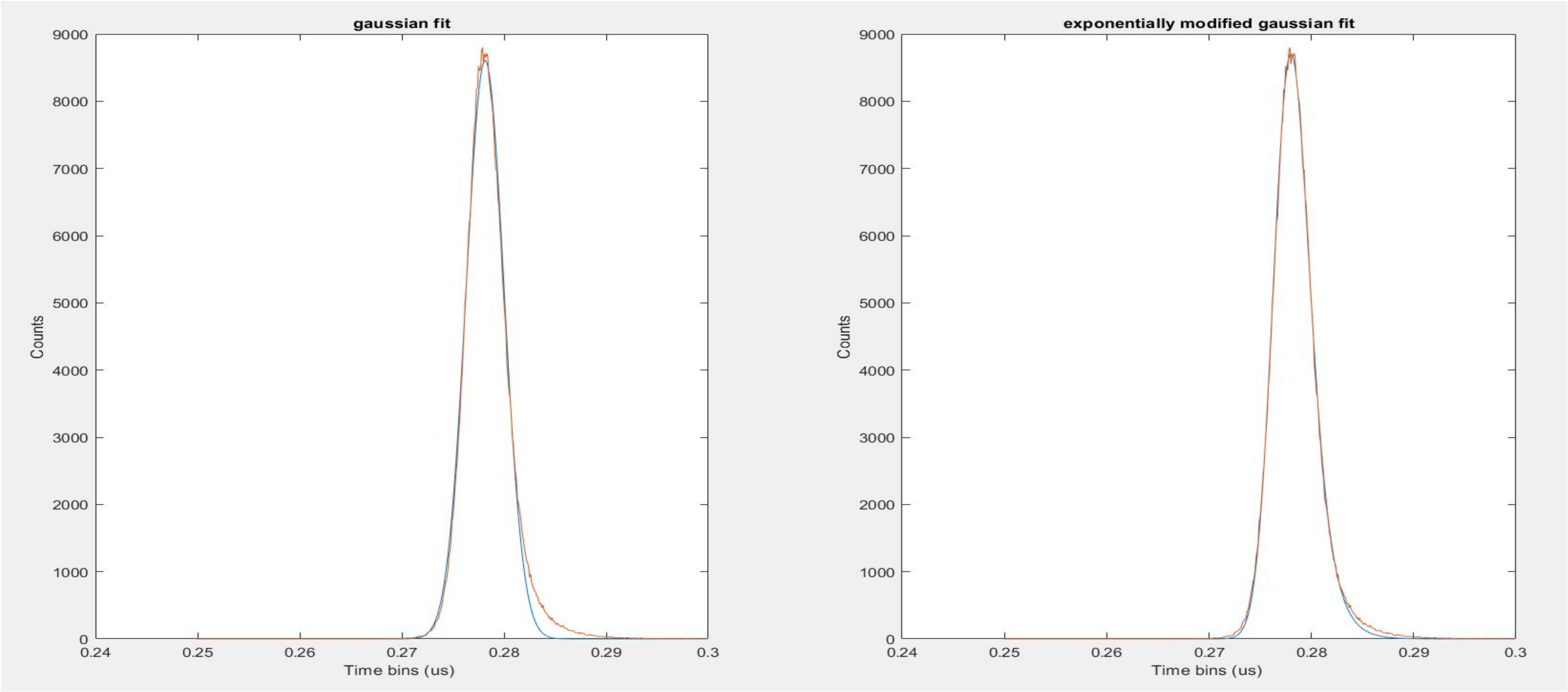
Single-Photon LiDAR Imaging:

- 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)

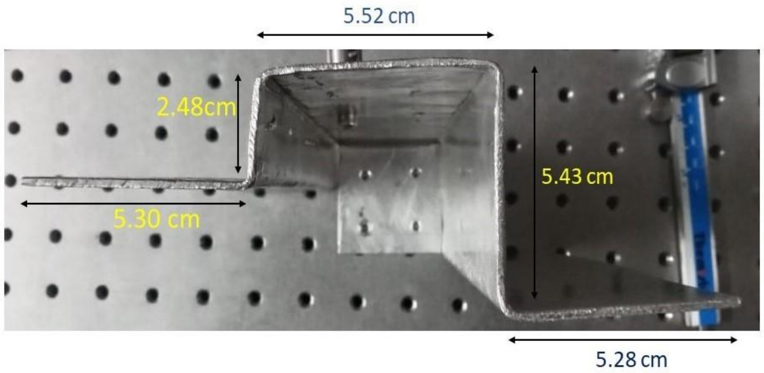
Limitations and Next steps:

- 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)



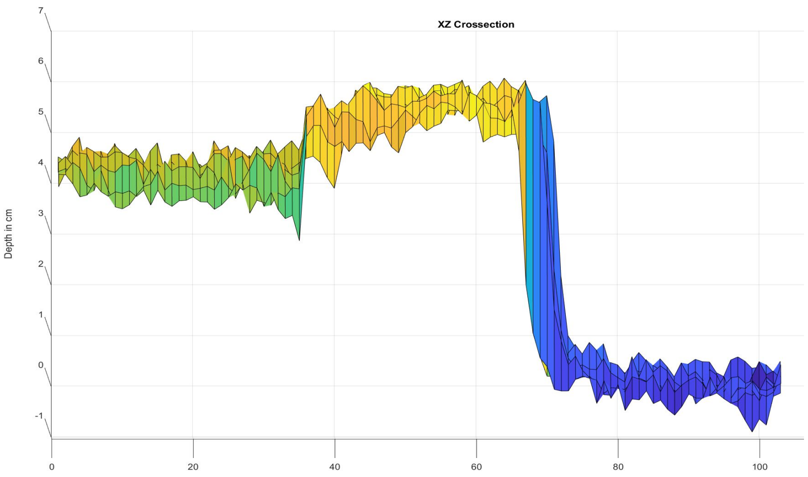


Figure: Reconstructed LiDAR image (RMSE: 9mm)

Present: Optical GKP states for Quantum Error correction

(September 2024 -)

Quasi-Phase matching using PPKPT

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

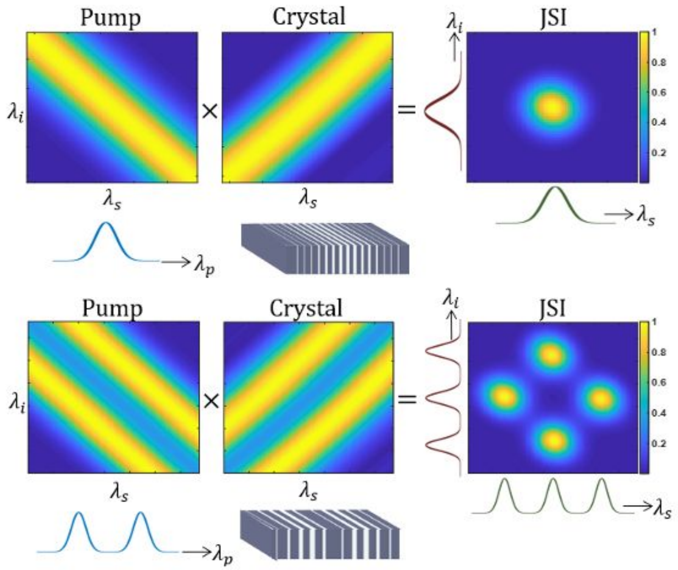
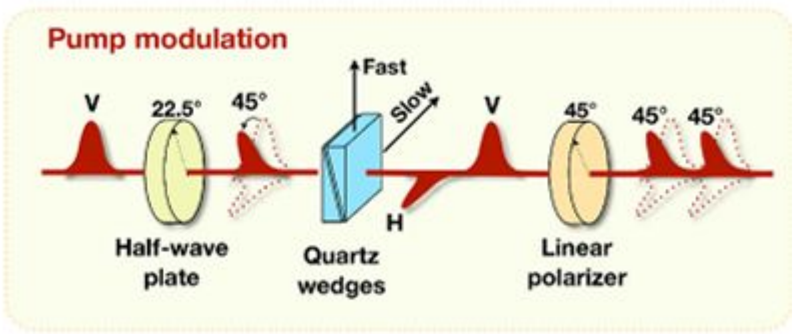


Fig. 1. Illustration of the 2-dimensional control over the JSI. Top - Gaussian-shaped pump spectrum and PMF resulting a round JSI. Bottom - double-Gaussian-shaped pump spectrum and PMF resulting a 4 lobe JSI.

Ref: Ady et al, 2020

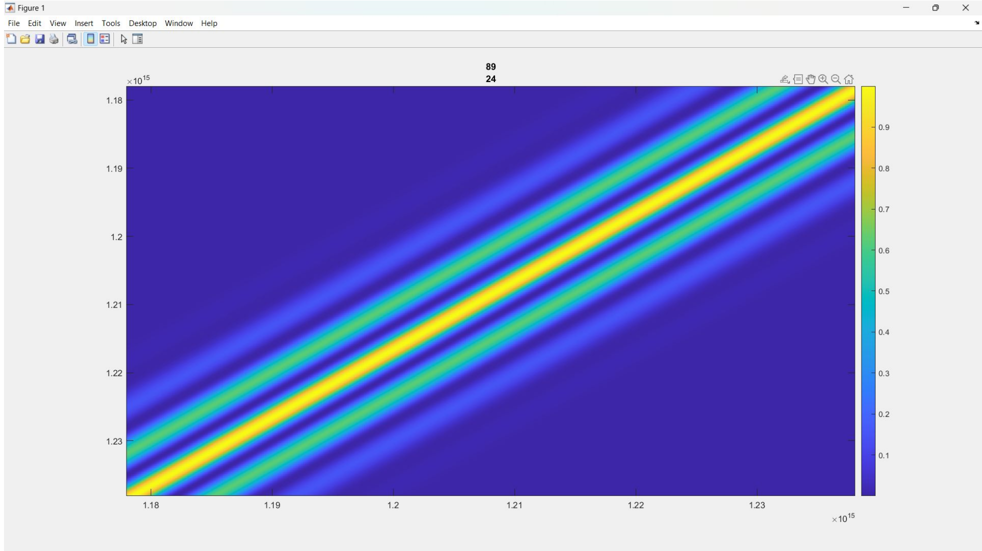
Quasi-Phase matching using PPKPT

- 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)