ARTEMIS

SPICA : Parametric Instability Mitigation in GW detectors

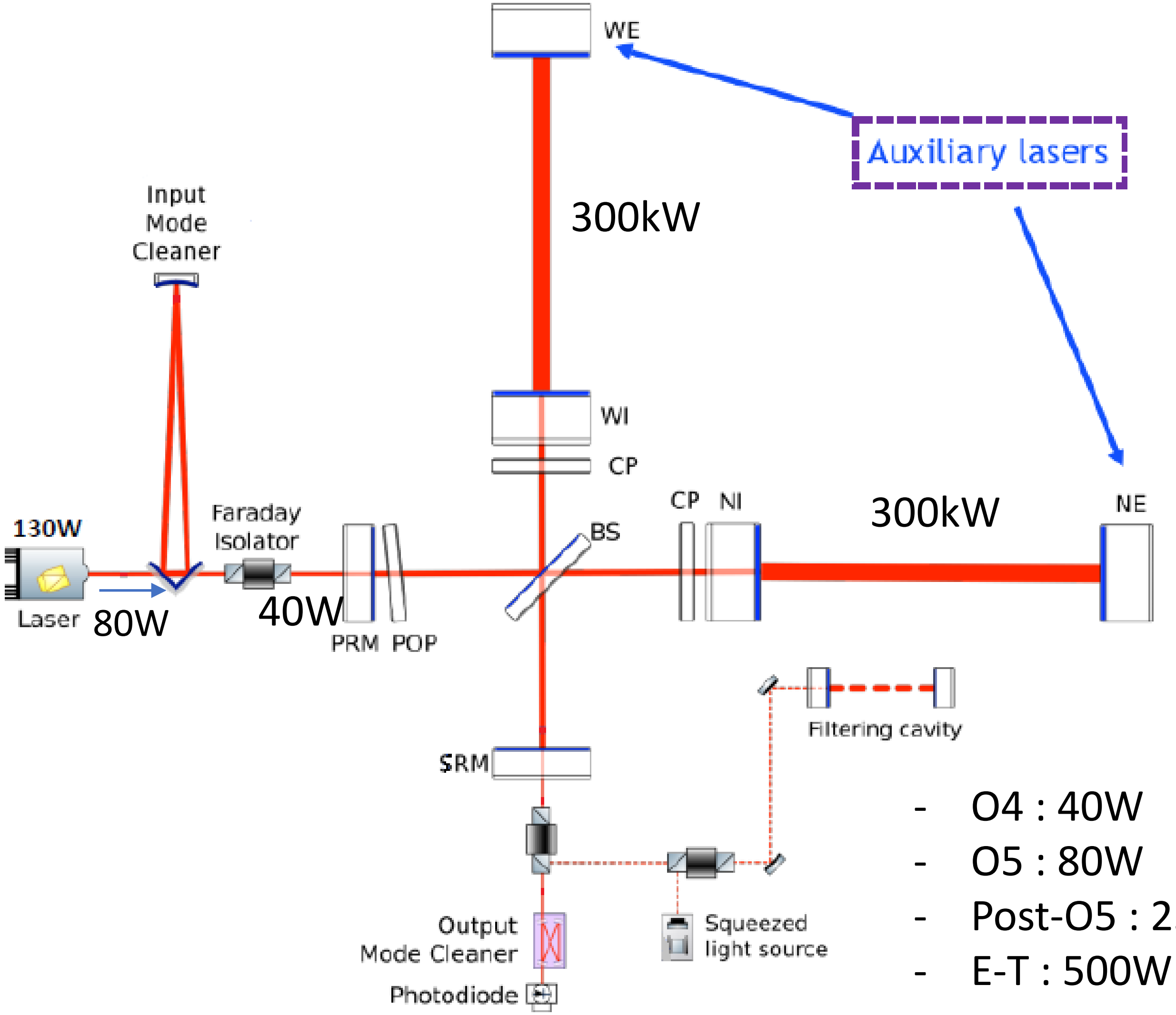
ARTEMIS, Observatoire de Nice

Thomas Harder (PhD), Remi Soulard, Margherita Turconi, Walid Chaibi

AG First-TF 2021

UNIVERSITÉ CÔTE D'AZUR   FIRST TF   cnrs

AdV+ project



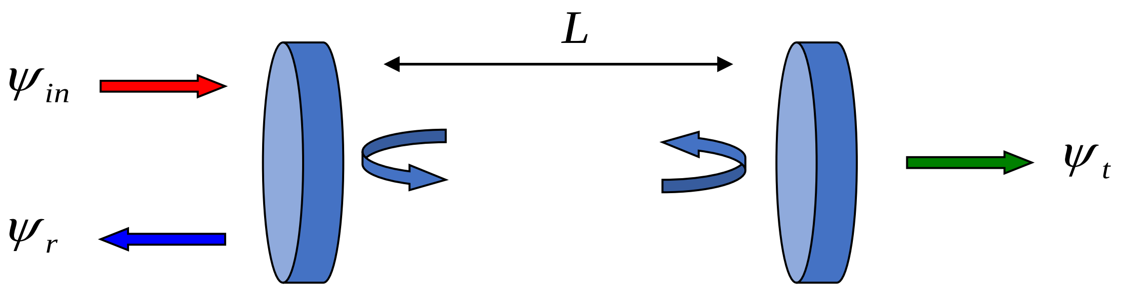
- O4 : 40W
- O5 : 80W
- Post-O5 : 250W
- E-T : 500W

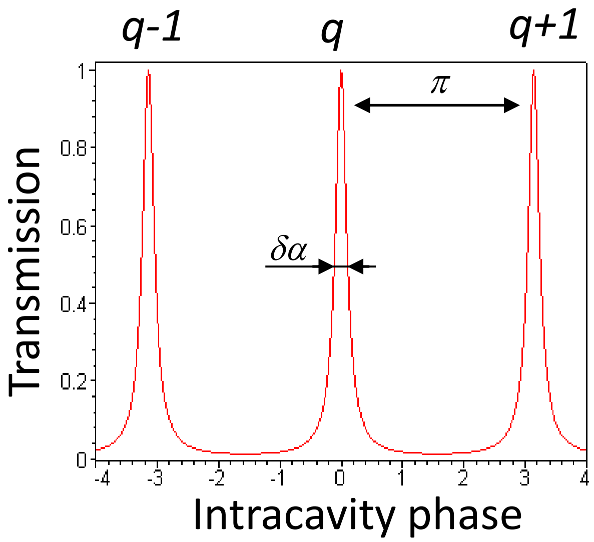
Outline

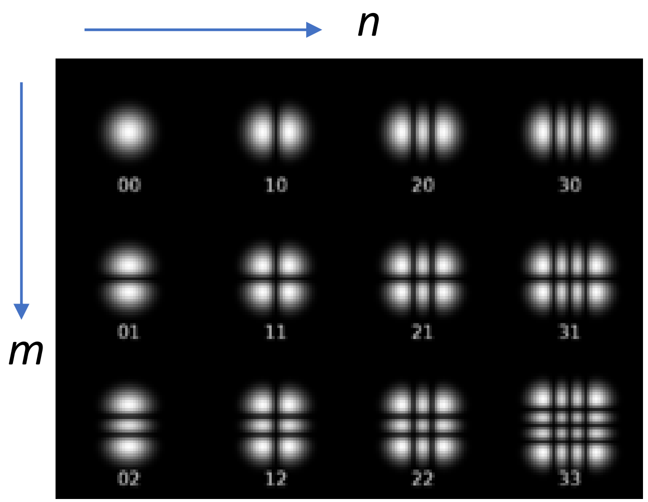
Parametric instabilities (Pis) are a real limitation to power increase

- What are Pis?
- Mitigation strategy
- Results

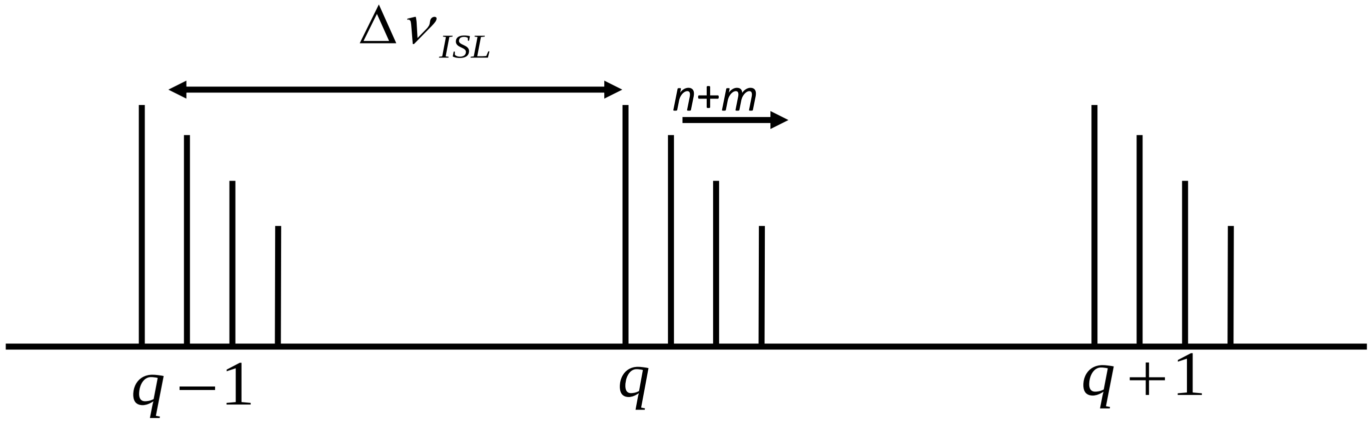
Linear optical cavity







HG modes



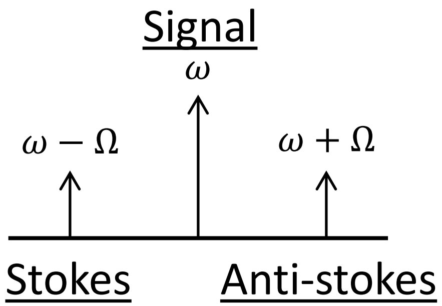
Stable cavity : non degeneracy of HG modes' resonance frequencies

Light scattering

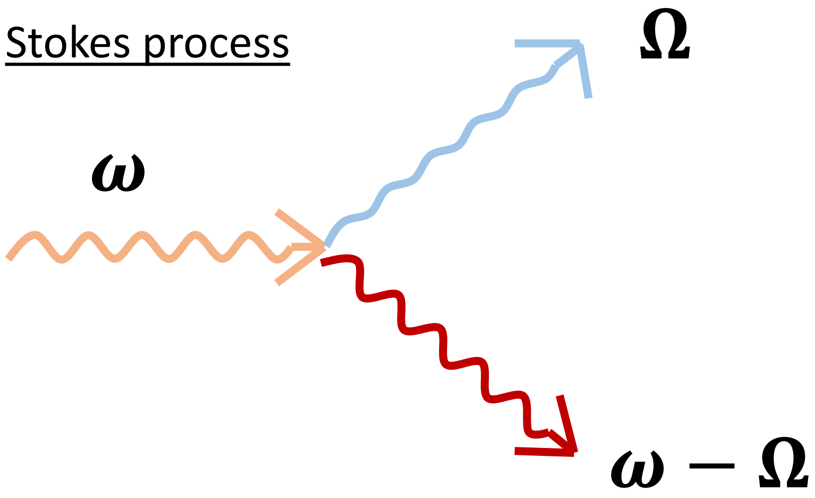
$$\delta x(t) = \delta x_0 \times \cos(\Omega t)$$

$$t_i \simeq t_f - \frac{2}{c}\left[L + \delta x\left(t_f - \frac{L}{c}\right)\right]$$

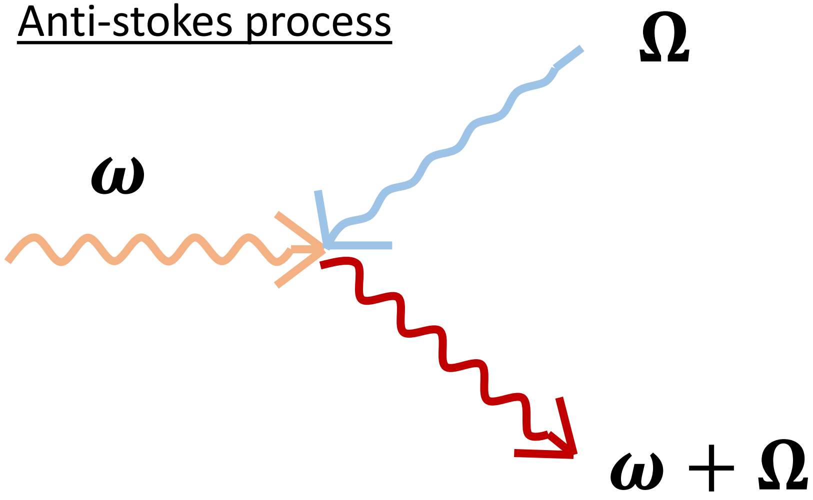
$$\mathcal{E}_-(t_f) = \mathcal{E}_+(t_i) = \mathcal{E}_0 e^{\imath \omega t_i}$$



Stokes process

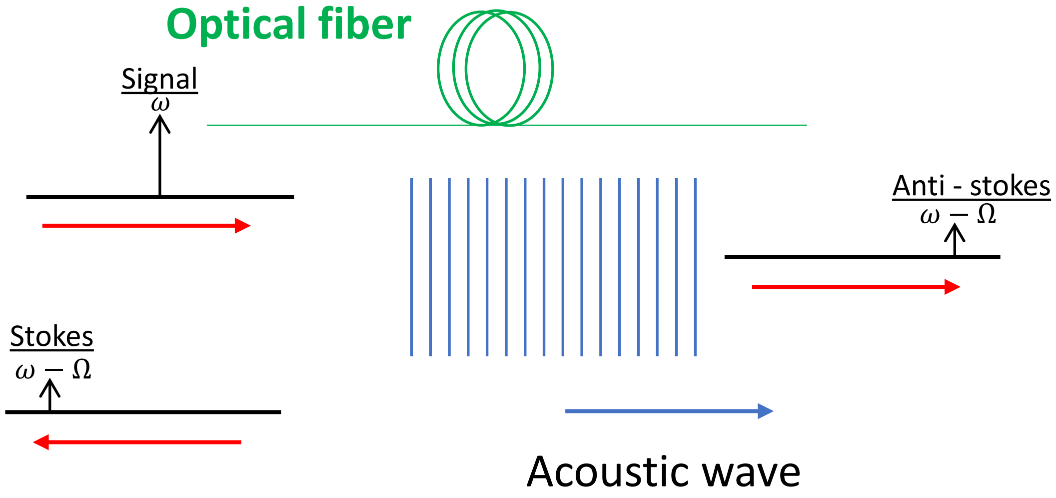


Anti-stokes process

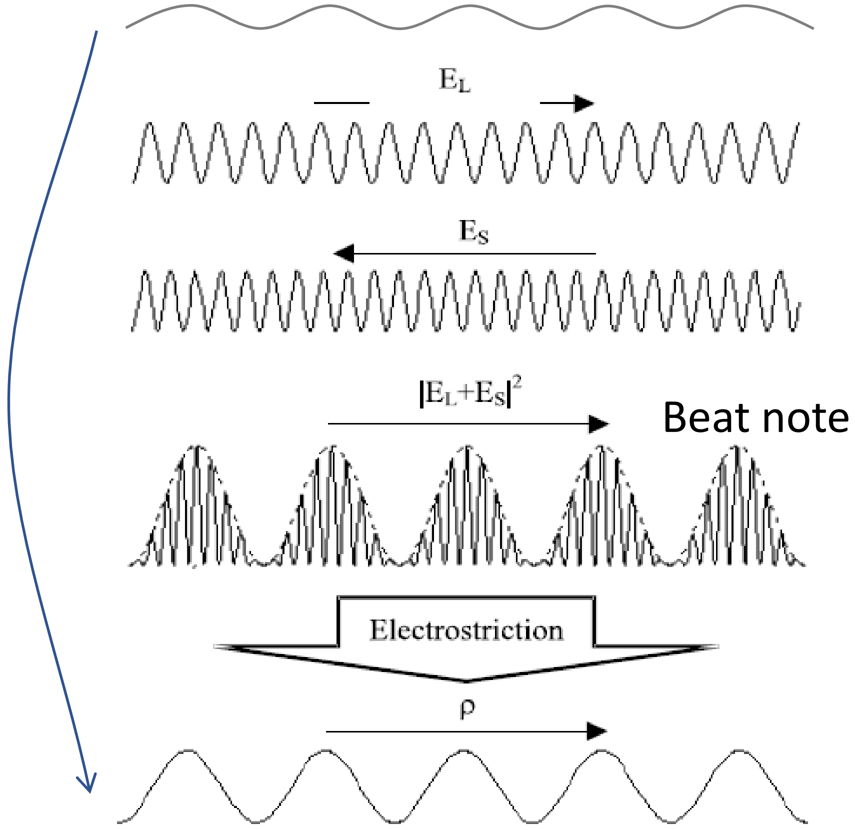


Brillouin scattering in fibers

Spontaneous Brillouin scattering

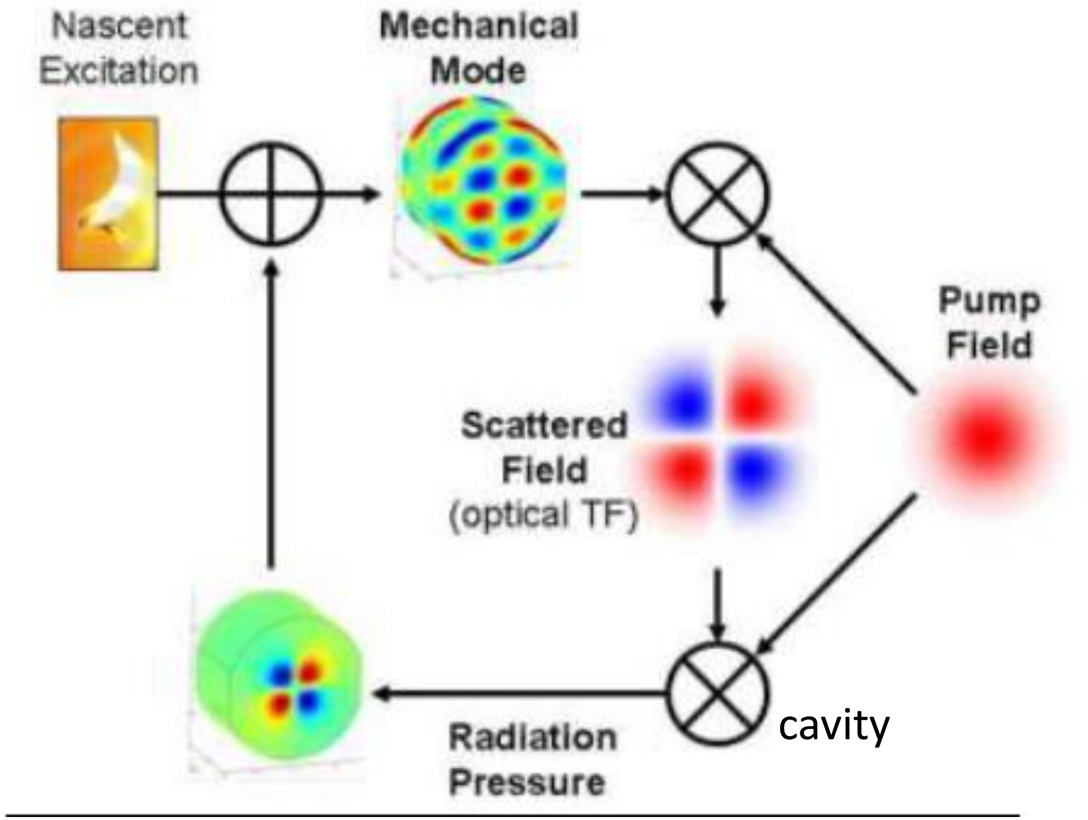


Stimulated Brillouin scattering



Parametric Amplification

PI due to mirrors internal modes



Evans et al, Phys. Lett. A, 374(4), 665-671 (2010)

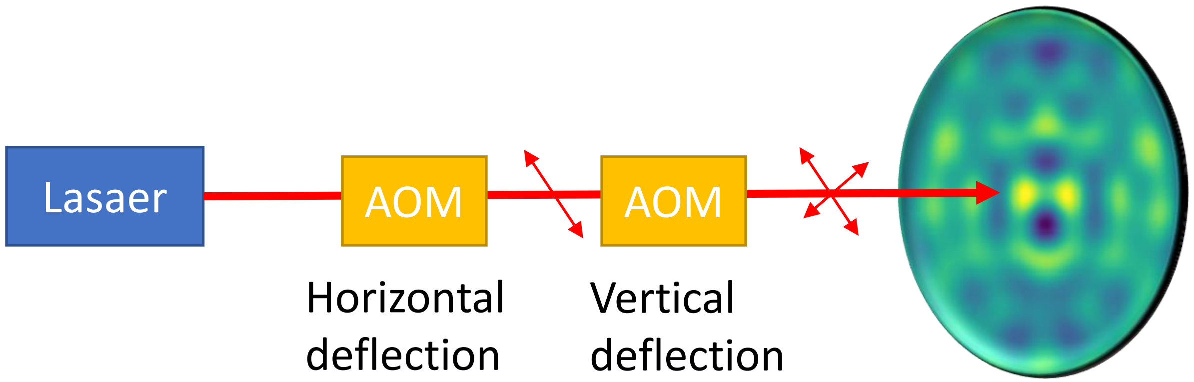
Instability condition

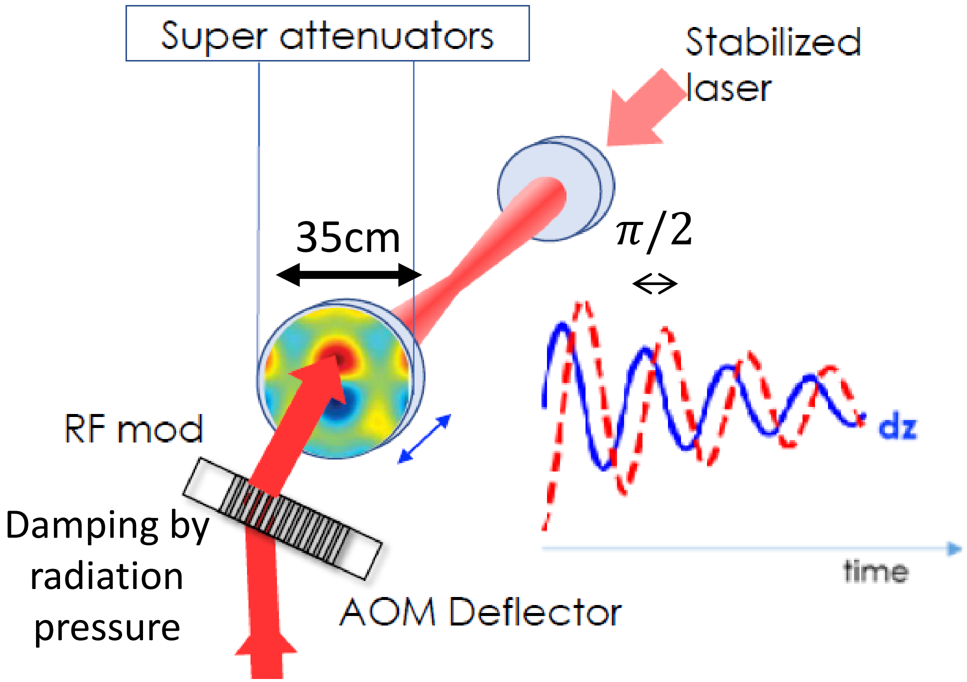
$$\mathcal{R} = \frac{P_{int} \times Q_m \times Q_{HOM}}{cL \times m\omega_m^2} \times \frac{B}{1+\left(\frac{\Delta\omega_{HOM}}{\omega_p}\right)^2} > 1$$

- **Parametric gain**: $\mathcal{R}$
- Intracavity power: P_{int}
- Mechanical quality factor: Q_m
- HOM optical quality factor: Q_{HOM}
- Overlap: B
- α mechanical mode energy: $m\omega_m^2$
- Cavity pole: ω_p
- HOM detuning: $\Delta\omega_{HOM}$

Radiation pressure-based mitigation

Passive : radius of curvature control, Mechanical dissipation
Active : Electrostatic control



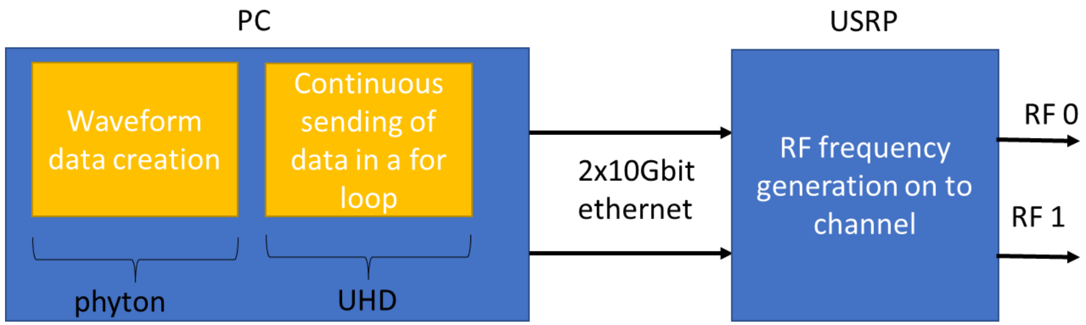


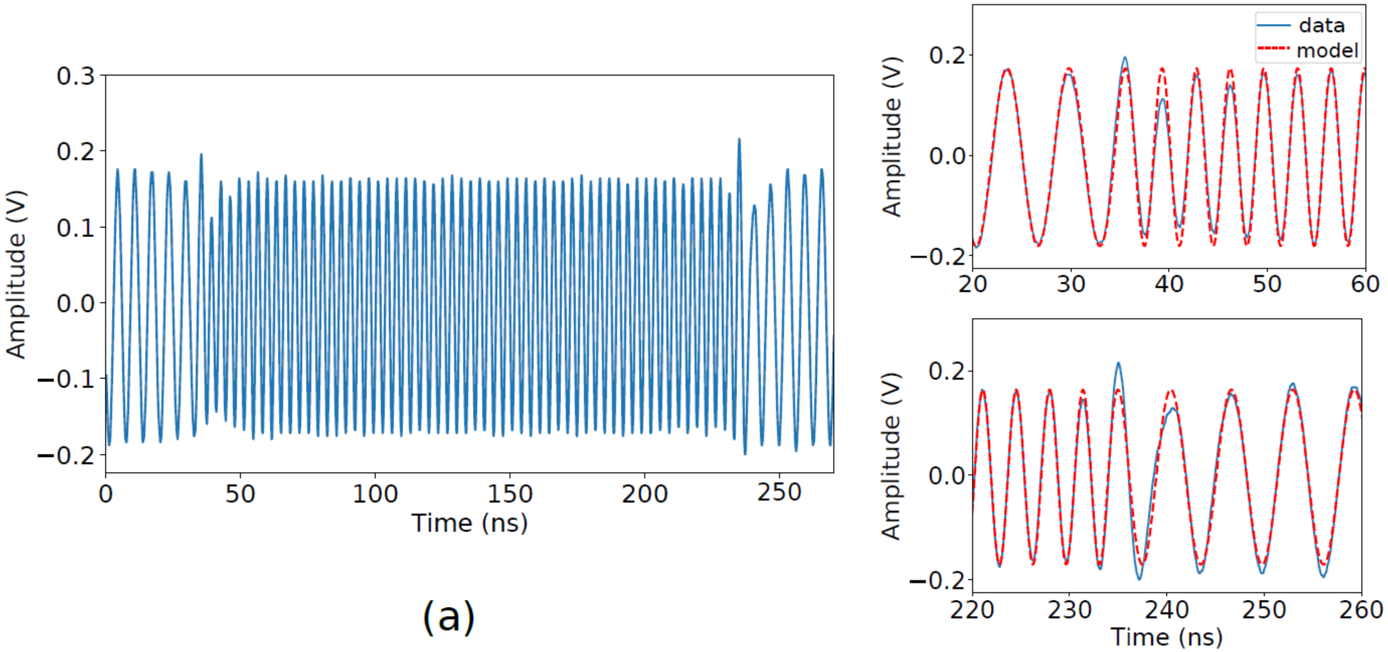
- Random access
- Fast deflection

- Mechanical damping
- Light scattering -> Optical damping

Fast and Random access : USRP

- Control via UHD software on linux machine
- IQ composition with carrier frequency up to 6GHz
- Change of frequencies within ~2-7ns

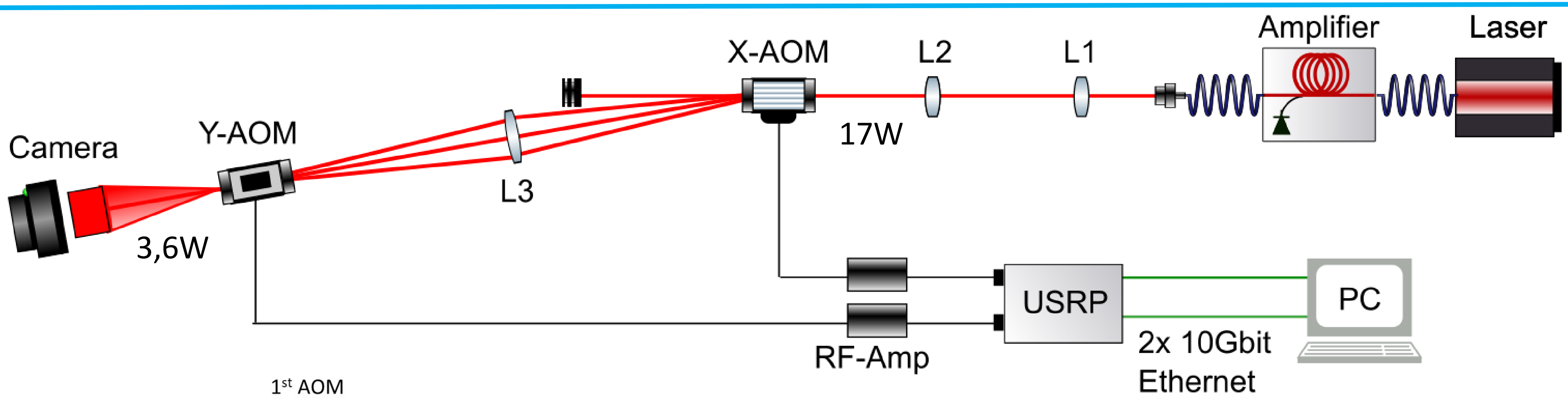


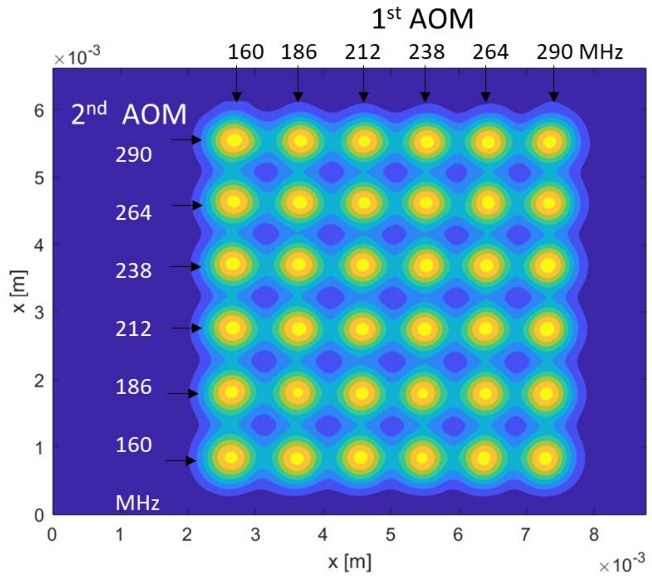


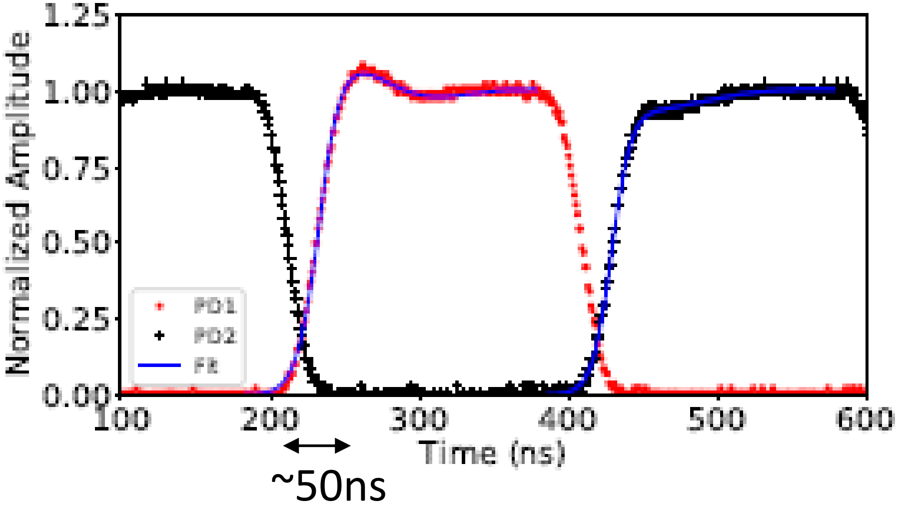
(a)

(b)

Fast Deflectors







$$\frac{\Delta\theta_{div}}{\Delta\theta_{def}} \simeq \frac{1}{6}$$

Conclusion

- Mitigation efficiency : Simulations to be conducted…

- Implementation for Post-O5 : Optical mitigation