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# Strong Optomechanical Coupling with OAM in Cavities

Optomechanical systems mediate interactions between optical and mechanical modes [1]. Thanks to this capability, they are very attractive for experiments in fundamental physics and the realization of optical sensors, interfaces, transducers and memory elements in classical and quantum regimes. We propose to exploit optomechanical coupling by using an ultra-low dissipation mechanical membrane [2], to realize transducers of linear and orbital angular momentum of light (Spin and OAM). In particular, the OAM is a very attractive degree of freedom due to its nature of infinite dimensionality. This unique peculiarity gives the possibility to transfer a wealth of information. We use the SAM-OAM converter q-plate, to produce light beams with OAM in our system due to the high generation efficiency and polarization control that provides this device [3,4] and that is required in systems at high laser power. The induced non-linear processes due to the high laser power must also be taken into account for the optomechanical coupling [5].
In our preliminary measurements in collaboration with CNR-IMEM, CNR-ISASI, FBK et UniNA, we obtained a frequency splitting for the mechanical modes, demonstrating that two spatial optical modes couple differently with the lower frequency and the higher frequency (M. Parisi et al. 2024 in preparation). In this activity, we aim to achieve optomechanical coupling in the quantum regime by using an ultra-low dissipation mechanical membrane in the middle of an optical cavity to achieve strong coupling. The optomechanical interaction Hamiltonian is of the form of the standard 'linearly'coupled optomechanical system

\begin{equation}
\hat{H} = - ihgx a^{†} a (b + b^{†})
\end{equation}

where a (a†) and b (b†) are the annihilation (creation) operators for the optical and mechanical modes respectively. The designed AOM-cavity apparatus can transfer through mechanical modes, the encoded information on optical beams with high fidelity [6]. The key element of this apparatus is an optical cavity with an ultra-low dissipation membrane in the middle. The cavity will be put in vacuum and at cryogenic temperature to minimize acoustic and thermal noise. The diagnostic systems will use interferometric techniques, high-resolution CCD cameras, and large-band detectors.

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## Title

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