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EPR experiment for a broadband quantum noise reduction in gravitational wave detectors

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Vacuum fluctuations entering the dark port of an interferometric Gravitational Wave (GW) detector are responsible for Quantum Noise (QN).
The high-frequency component of QN is Shot Noise (SHN), while the low-frequency one is Radiation Pressure Noise (RPN).
The sensitivity of the present detectors is only affected by the first, being the RPN covered by techinical noises.
SHN reduction, injecting Frequency Independent Squeezing (FIS) from the dark port of the interferometer, has been already demonstrated in GEO, LIGO and, recently, also in Advanced Virgo.
In the near future, when low-frequency technical noises will be reduced and the laser power will be increased, RPN will limit the detector sensitivity, then a braodband QN reduction will be needed.
Since RPN noise is related to the vacuum amplitude fluctuations, one needs two different squeezing angles for low and high frequencies. Starting from phase squeezed frequency independent (FI) vacuum, produced by a degenerate Optical Parametric Oscillator (OPO), one can obtain a Frequency Dependent Squeezing (FDS) by the injection of the FI squeezed vacuum in an external Filter Cavity (FC), before injecting it into the interferometer.
The required squeezing angle rotation must occur around the frequency of the interferometer pole (i.e. around 100 Hz). The additional requirement to limit intra-cavity losses to a few percent implies that the FC must be hundreds of meters long.
Injecting Einsten-Podolsky-Rosen (EPR) entangled vacuum fields into the interferometer can be a valid alternative to the use of a FC. It will allow to abtain the frequency dependent rotation angle with a more compact system avoiding, the expensive infrastructure needed for the Filter Cavity,
including all the related control systems and the interface optics between the filter cavity and the interferometer.
The method for obtaining the frequency dependent rotation angle using EPR entangled beams and the experiment that we are developing from a FIS source, which is currently operating at the Virgo site, will be described in the present talk.
The first step will be the realization of a table-top demonstrator that will make use of a test cavity instead of a gravitational wave interferometer. The following step will be the design and the realization of an EPR experiment to inject the entangled beams in Advanced Virgo.

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