High-Frequency Analysis of Diffraction within the Tubes of an Interferometric Detector of Gravitational Waves

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Gravitational waves have been very recently detected thanks to very long base interferometers like LIGO, Virgo and KAGRA (B.P. Abbott *et al.*, Phys. Rev. Lett., 116 (2), pp. 061102-061118, 2016). These instruments are based on Fabry-Perot optical interferometers, where the (quadrupole) spacetime ripples due to a gravitational wave cause an intensity modulation of the dark interference fringes. Being the differential arm length perturbations extremely small, ($\simeq 10^{-21}$m), maximum precision in the whole optical set-up is required, and all possible noise sources must be minimized.

In the existing instruments infrared lasers are used Laser beam travels the arms back and forth between a pair of mirrors and, since path length is to be measured, any source of multipath would cause interfering noise. To minimize this noise arms are in vacuum, to avoid air molecules and dust scattering, yet diffraction due to the finite size of the end-mirrors and other optical components may cause a small amount of stray rays Absorbing baffles or irises are hence placed along the beam path to intercept stray light that would eventually reach the pipe walls - which are coupled to environmental noise - and re-couple to the main FP cavity mode (M.R. Smith, LIGO Document G1100232, 2011). Baffles themselves can be, anyway, source of diffraction and hence noise which degradates performances. Even if baffles are already present in currently working interferometers, efficient modeling of baffle diffraction is needed in order to optimize baffle design for both present future generation detectors.

A high-frequency electromagnetic analysis will be here applied to a baffle (Geometry in Fig. 1a), using a Gaussian beam model for the primary field. The proposed solution is analytic and physically readable, and suitable to be projected onto the Gauss-Laguerre beam basis, which is an efficient instrument to describe focused beams (A.E. Siegman, *Lasers*, Univ. Science Books, Sausalito (CA), 1986). Fig. 1b shows preliminary results attained on a beam with a vertically (y) polarized electric field of 1Vm^{-1} peak amplitude, a waist $w_0 = 100\mu$m and at a wavelength $\lambda = 10\mu$m. Baffle has a $a = 70$mm radius and is placed at $z_b = 500$mm from the beam source. Diffracted field is plotted on the two principal planes $\varphi = 0$ and $\varphi = 90°$ at a distance $z_s = 2$m from the origin.

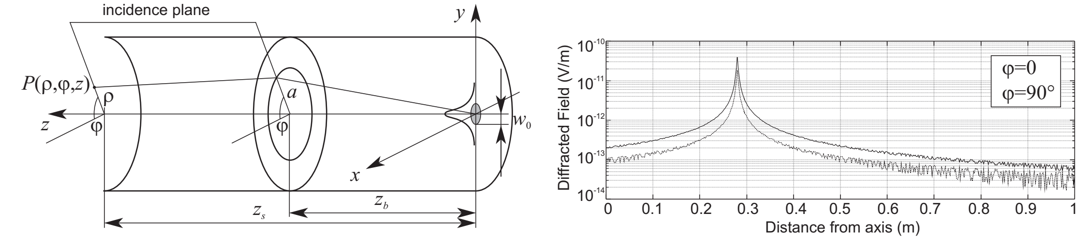

Figure 1: left: Geometry of the problem; right: diffracted field on two principal planes.