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The Gouy phase of long-range Gauss-Bessel beams

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One of the processes that is assumed to be well understood, is that any fundamental Gaussian light beam experiences an axial phase shift of radians with respect of a reference plane wave when passing through its focus. For a higher-order Hermite-Gaussian mode with mode indices (m, n) this phase is multiplied by a factor of $(1 + m + n)$. For a higher-order Laguerre-Gaussian mode with mode indices (l, p) the corresponding multiplication factor is $(1 + |l| + 2p)$. The modulus sign accounts for the fact that the azimuthal mode index l (i.e. the on-axis topological charge of the point phase dislocation known as an optical vortex) can be either positive or negative.

In our previous studies, we have demonstrated the possibility to generate long-range and quasi-non-diffracting Gauss-Bessel beams (GBBs) by creating and annihilating multi-charge optical vortices [1,2]. The method was demonstrated even to work for sub-7-femtosecond pulses [3]. Recall that the Gouy phase is measured relative to that of an infinite plane wave, and an infinite plane wave does not experience diffraction. One might think that quasi-nondiffracting GBBs have zero (or negligible) Gouy phase.

In the only two experimental works [4,5] we are aware of, the Gouy phase of GBBs is found to change linearly over short distances (up to 5 within 1 mm [5] and up to 6 within 6 μm [4]).

In this talk we will describe an analytical theoretical model for the Gouy phase of long-range GBBs accounting for the relevant experimental parameters. In particular, under relatively weak focusing of the initial hollow ring-shaped beam, the Gouy phase of the GBB is found to change linearly at a rate of some 0.2/cm over a distance of 45 cm. Under moderate focusing, the slope can reach (1.0/mm) over distances exceeding 4 millimeters. The theoretical results are found in a good quantitative agreement with the experimental data.

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Primary authors: Dr STOYANOV, Lyubomir (Friedrich Schiller University, Germany & Sofia University "St. Kliment Ohridski", Bulgaria); Dr STEFANOV, Aleksander (Sofia University "St. Kliment Ohridski", Bulgaria & Bulgarian Academy of Sciences, Bulgaria); Prof. DREISCHUH, Alexander (Sofia University "St. Kliment Ohridski, Bulgaria); Prof. PAULUS, Gerhard G. (Friedrich Schiller University (Germany) & Helmholtz Institute Jena (Germany))

Presenter: Prof. DREISCHUH, Alexander (Sofia University "St. Kliment Ohridski, Bulgaria)

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