Self-pumped phase conjugation of light beams carrying orbital angular momentum

M. Woerdemann, C. Alpmann, and C. Denz
Institut für Angewandte Physik,
Westfälische Wilhelms-Universität Münster
e-mail: woerde@uni-muenster.de

Abstract: *The properties of vortex beams reflected by a phase-conjugating mirror are investigated. We prove that the topological charge of the vortex beam is maintained and thus the orbital angular momentum in the laboratory frame is reversed.*

Light beams with screw phase dislocations are known to carry optical orbital angular momentum [1]. A novel field of applications for these beams is optical tweezers where angular momentum is transferred to microscopic samples e.g. to drive micro machines [2].

A screw phase dislocation may also be called optical vortex. It possesses a topological charge, equal to the integer m, where m is defined by the $2\pi m$ phase change on any closed circuit around the dislocation center. The topological charge also indicates the optical orbital angular momentum, which is given as $m\hbar$ per photon. The sign of m is defined by the handiness of the screw-like surface of fixed phase in space. It is important to note that the sign of m thus is always given in the frame of reference of the beam, while optical angular momentum conveniently is given in the laboratory frame of reference.

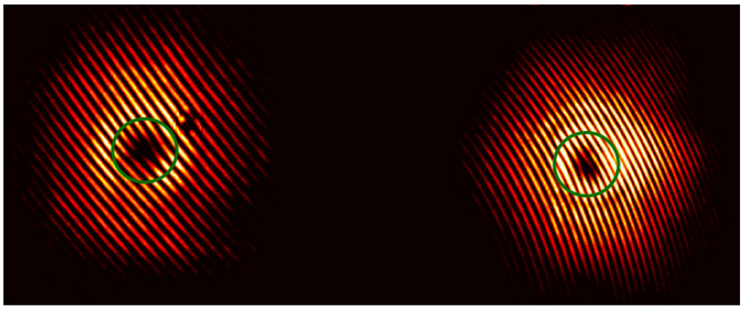

Figure 1: Interference pattern of a plane wave and a vortex reflected by a phase-conjugating mirror (left) and a conventional mirror (right), respectively. It is clearly seen that the topological charge of the vortex is reversed. The circle indicates the center of the phase dislocation.

It is a well known and often used fact, that the sign of the topological charge of a vortex beam is reversed when it is reflected by a mirror [3]. Since the direction of propagation also reverses in normal reflection, orbital momentum is conserved. The situation is different for a phase-conjugating mirror. Due to the time reversal property of the phase-conjugating mirror, the incident and reflected wavefront surfaces match perfectly [4]. As a result, the topological charge does not change sign and the optical orbital angular momentum is reversed. Hence, the difference in angular momentum of $2m\hbar$ per photon needs to be transferred to the phase-conjugating mirror [3].

In this contribution we demonstrate a self-pumped photorefractive phase-conjugating mirror [5] that is used to investigate these fundamental characteristics. It is shown that this implementation of a phase-conjugating mirror is suitable to produce very stable, high-fidelity phase conjugation of vortex beams. We directly compare the reflection properties of a conventional mirror to that of a phase-conjugating mirror. The three dimensional interference pattern in front of the phase-conjugating mirror is studied and applications in optical traps are suggested.

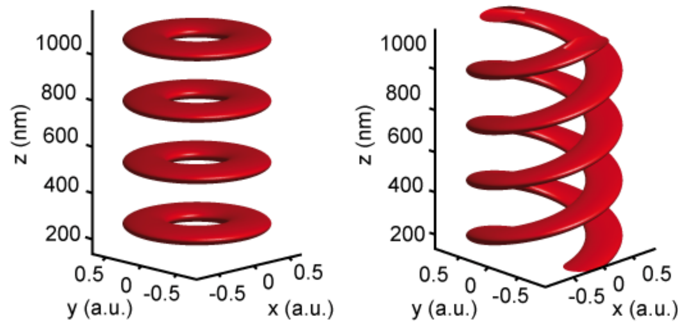

Figure 2: Interference pattern of a first order LG beam and its reflection. The reflection is performed by a conventional (left) and a phase-conjugating mirror (right), respectively. A wavelength of λ = 532 nm is assumed.

[1] I.V. Basistiy, M.S. Soskin, M.V. Vasnetsov, “Optical wavefront dislocations and their properties”, *Opt. Comm.* **119**, 604 (1995)
[2] K. Ladavac, D.G. Grier, “Microoptomechanical pumps assembled and driven by holographic optical vortex arrays“, *Opt. Express* **12**, 1144 (2004)
[3] A.Y. Okulov, “Angular momentum of photons and phase conjugation”, *J. Phys. B: At. Mol. Opt. Phys.* **41**, 101001 (2008).
[4] R.A. Fisher (ed), “Optical phase conjugation”, *Academic Press, Inc.* (1983)
[5] J. Feinberg, “Self-pumped, continuous-wave phase conjugator using internal reflection”, *Opt. Lett.* **7**, 486 (1982)