Comment on "Local Observations of Phase Singularities in Optical Fields in Waveguide Structures"

In [1] Balistreri *et al.* have presented results obtained by means of an interesting variant of the photon scanning tunneling microscope, commonly used for the sensing of evanescent wave components, with interferometric heterodyne detection. The presented measurements are of guided optical modes in a channel waveguide and they are a continuation of previously reported studies from the same research group [2]. The novel feature here, however, is the heterodyne detection scheme by which they claim to have observed both the amplitude and the phase of guided optical waves and, in particular, that they have observed "phase singularities in optical fields in waveguide structures" as explicitly stated in the title of their Letter [1]. These "phase singularities" have been observed when exciting simultaneously the TE_{00}, the TE_{01}, and the TM_{00} mode in the waveguide, but with the main features attributed to only the TE_{00} and the TM_{00} mode. As these two modes are orthogonal they do not interfere along the waveguide, as correctly stated by the authors. Thus, the total intensity of these modes I_{00} at any point along the waveguide is simply found as the sum of the intensity carried by each, i.e.,

$$I_{00} = I_{\mathrm{TE}_{00}} + I_{\mathrm{TM}_{00}} > 0 . \qquad (1)$$

In this expression we have stressed the fact that the intensity is always larger than zero. It is well established that a necessary condition for the existence of a phase singularity is that the field amplitude (or intensity) equals zero at such a point thus making the corresponding phase indeterminate [3]. Since the excited waveguide modes do not interfere, there are no points of zero intensity, the phase of each mode is well determined, and phase singularities of the optical fields along the waveguide cannot exist. The beating of the recorded amplitude signal (referred to by the authors as "quasi-interference") with points of zero signal is a signature of the specific observation technique and the reported phase singularities of the waveguide fields are therefore an artifact of the chosen method devoid of any physical relevance.

To account for the features observed let us write down an expression for the amplitude of the excited fiber modes of the probe as follows (with the common assumption of a passive probe) [4,5]:

$$A_m(\boldsymbol{r}) = \frac{1}{4\pi^2} \iint \boldsymbol{H}_m(\boldsymbol{k}) \cdot \boldsymbol{F}(\boldsymbol{k}) \exp(i\boldsymbol{k} \cdot \boldsymbol{r})\, d\boldsymbol{k} , \qquad (2)$$

where A_m is the amplitude of the mth excited fiber mode, $\boldsymbol{r} = (x, y)$ is the position of the probe in the plane of the sample, $\boldsymbol{k} = (k_x, k_y)$ is the projection of the wave vector onto this plane, $\boldsymbol{F}(\boldsymbol{k})$ is the vector amplitude of the appropriate plane-wave component (obtained from a plane-wave decomposition of the incident field), and $\boldsymbol{H}_m(\boldsymbol{k})$ is a vectorial coupling coefficient that sets the coupling strength of each plane-wave component to the mth fiber mode and incorporates all addition changes to the state of polarization unto the detection. Consequently, $\boldsymbol{H}_m(\boldsymbol{k})$ can be adjusted so that orthogonal waveguide modes couple to the same fiber mode and cause the reported quasi-interference [1,2]. It is thus clear that locations of apparent phase singularities are due to destructive interference of the excited fiber modes (and not the waveguide modes) resulting in a zero signal and giving the false appearance of singularities in phase of the waveguide fields. The exact position of these points ought therefore also to change with any additional birefringence in the detection system caused by, e.g., additional bending of the fiber probe. Curiously enough, if the authors had taken precautions not to excite the TM_{00} mode, they could have observed true phase singularities in the waveguide fields by the interference of the TE_{00} and the TE_{01} mode.

Finally, we point out that the claimed high resolution of their technique from the observation of parallel fringes in phase recordings (see Fig. 2c in Ref. [1]) is by no means a sufficient demonstration of a high subwavelength-sized resolution. It is a well-established fact that the periodicity will appear in most cases even with a poor probe and it is for the same reason that even intensity gratings (produced by a standing evanescent wave) on a flat surface are not adequate objects for testing the resolution capabilities of any near-field optical microscopes [5].

Brian Vohnsen[1,*] and Sergey I. Bozhevolnyi[2]
[1]Laboratorio de Optica (Departamento Fisica)
Campus de Espinardo (Edificio C)
Universidad de Murcia
ES-30071 Murcia, Spain
[2]Institute of Physics, Aalborg University
Pontoppidanstræde 103
DK-9220 Aalborg Ø., Denmark

Received 17 April 2001; published 28 November 2001
DOI: 10.1103/PhysRevLett.87.259401
PACS numbers: 42.25.Bs, 07.60.Ly, 07.79.Fc, 42.25.Hz

*Email address: vohnsen@um.es

[1] M. L. M. Balistreri, J. P. Korterik, L. Kuipers, and N. F. van Hulst, Phys. Rev. Lett. **85**, 294 (2000); Phys. Rev. Focus **6**, 1 (13 July 2000).
[2] M. L. M. Balistreri, A. Driessen, J. P. Korterik, L. Kuipers, and N. F. van Hulst, Opt. Lett. **25**, 637 (2000).
[3] I. V. Basistiy, M. S. Soskin, and M. V. Vasnetsov, Opt. Commun. **119**, 604 (1995).
[4] J.-J. Greffet and R. Carminati, Prog. Surf. Sci **56**, 133 (1997).
[5] S. I. Bozhevolnyi, B. Vohnsen, and E. Bozhevolnaya, Opt. Commun. **172**, 171 (1999).

