P029

Two beam multiplexing in a multimode periodic segmented waveguide

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Abstract: The purpose of this article is to show that a beam multiplexing can be achieved in Multimode Periodic Segmented Waveguide. The beam multiplexing is based on properties of ray and wave chaos that have been revealed on such device. Two incident optical beams remain collimated all along the propagation into the waveguide without interfering if their associated trajectories are constructed on resonances of the Poincaré section.

A Multimode Periodic Segmented Waveguide (MPSW), sketched in figure 1, consists in an array of high refractive index guiding segments embedded in a low refractive index substrate. These particular waveguides are well known to be very interesting for many purpose for linear an nonlinear applications in integrated optics domain [1–3]. Beside this, recent works have shown that MPSW could be promising and versatile systems in which ray and wave chaos could be studied and used.
Recent works have shown that for particular waveguide configurations, MPSW exhibits complex rays' dynamics compared to classical uniform waveguides which can be regular or chaotic depending on the initial input conditions. In the case of highly multimode waveguides, where the geometrical assumption of ray propagation remains valid, the extension of the geometric analysis to the wave domain shows reminiscence of the complex rays' dynamics. Thus, a complex and non intuitive light behaviour can be observed in MPSW such as, for example, an imput beam, properly injected in the structure, does not diffract but remains collimated during the propagation in the MPSW unlike classical waveguide where the input beam is quickly dispersed on several modes.
In order to develop such a complex ray and wave dynamics, MPSW must have a longitudinal index periodicity associated with a non harmonic (gaussian) transverse index profile for the guiding segments[4]. The complex ray dynamics can be clearly identified by the use of the Poincaré section which is a convenient and widely used representation of a periodically perturbed nonlinear system. It consists in a projection of the trajectory (x,θ,z) onto the phase plane (x,θ) at positions $z=n\,\Lambda$, n=1,2,3,... where Λ represents the segmentation period of the waveguide. Poincaré sections revel that the dynamic may be characterized by the presence of a parametric nonlinear resonance which manifests itself through a period-locking between two characteristic periods of the

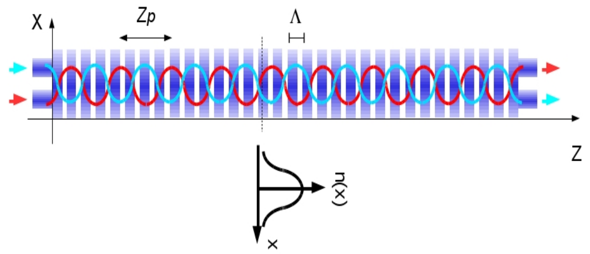

Fig 1: A schematic of a classical Multimode Periodic Segmented Waveguide with a transverse gaussian index profile in high index segments. For two beam multiplexing demonstration, two input and output waveguides have been added. A typical ray path is superimposed on the waveguide, the focusing length of the ray is Zp.

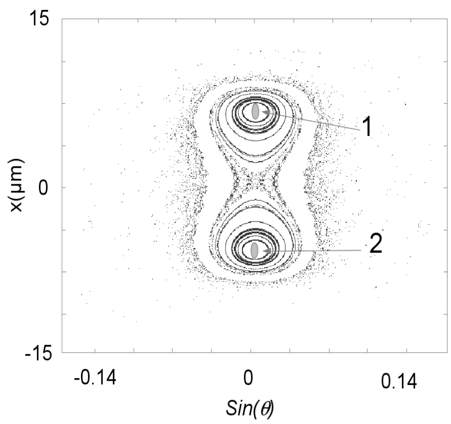

Fig 2: Poincaré section of the waveguide that exhibits two main resonances. Positions of the input beam are noted 1 and 2.

system: the segmentation period Λ and the focusing period Zp of the propagating ray. Resonances play a key role in the rays' dynamics. If an incident ray is injected in a resonance, then the ray trajectory is *trapped* and remains confined in the resonance. Thus, an incident beam propagates without diffracting into the waveguide if its associated trajectory is constructed on a resonance of the Poincaré section.

The beam multiplexing is performed in a waveguide configuration that exhibits two main resonances in the Poincaré section (see figure 2). Two beams are simultaneously injected in the two resonances of the Poincaré section (positions "1" and "2" noted on figure 2). The amplitude of the field of the second beam is reduced compared to the first beam in order to get clear picture of the two superposed beams in the waveguide. The field intensity distribution is shown in figure 3, the two beams coexist in the waveguide during the propagation without diffracting and interfering because they simultaneously occupy different positions in the phase space. The transverse field distribution of the output of the waveguide clearly demonstrates that the two input beams remain unchanged and identical to the input field profile. Regarding the propagation losses, despite the index discontinuity due to the segmentation, the calculated propagation losses are very low, 0.01 dB/cm which is two order of magnitude lower than the propagation losses induced by the waveguide fabrication process.

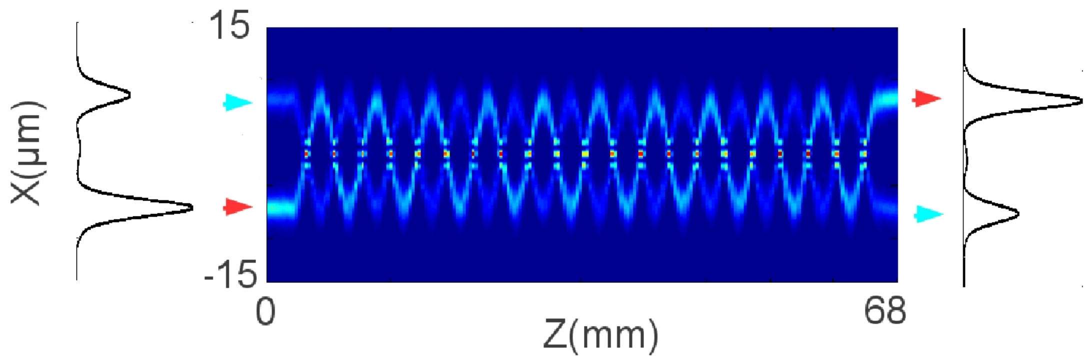

Fig 3: Two input beams injected simultaneously in the two resonances via the two input waveguides. The two Gaussian beams remain collimated without interfering each other. The output exhibits two well separated Gaussian fields.

What has mainly interested us with this work is to show that beam multiplexing can be achieved in MPSW. A simple two beams multiplexing has been numerically demonstrated which provides a preliminary numerical study of this new spatial multiplexing scheme. Nevertheless, this new kind of multiplexing may be useful to achieve specific functions in some integrated optical devices. For example, as it can be seen on figure 3, the two beams are spatially separated during the propagation excepted at the crossing point at the centre of the waveguide which means that adding an index perturbation localised in a suitable way will perturb the propagation of only one of the two beams.

This work may also precede a promising field of investigation where higher number of multiplexed beams can be obtained for various waveguide configurations that exhibits multiples resonances in the Poincaré section [4].

References

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