

# Impact of higher-order dispersion on geometric parametric instability in GRIN multimode fibers

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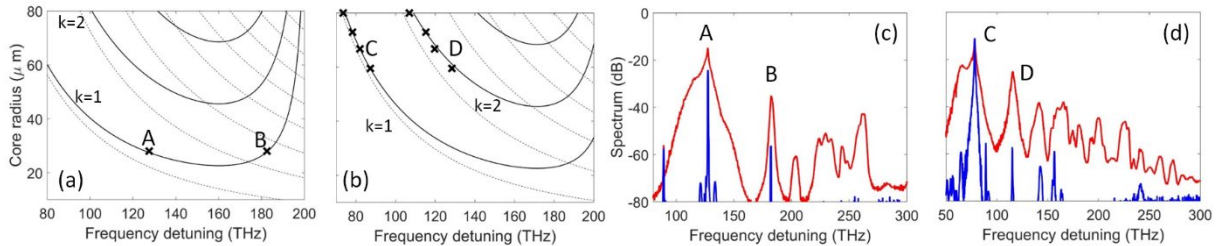
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Light propagating in a graded-index (GRIN) multimode fiber experiences periodic self-imaging which can induce, at high intensity, a Kerr refractive index grating with a typical sub-millimeter period. This grating is at the origin of geometric parametric instability (GPI) [1], which has been observed only recently [2]. The frequency of the bands generated from this process are given by:

$$\beta_e(\omega) + \bar{\gamma}P = k\pi/Z, \quad (1)$$

Where  $\beta_e(\omega) = \sum_{n \geq 1} \frac{\beta_{2n}}{(2n)!} (\omega - \omega_0)^n$  is the even part of dispersion relation,  $\bar{\gamma}$  is the average nonlinear parameter (defined as in [3]),  $P$  is the pump power,  $Z$  is the period of self-imaging and  $k \geq 0$  is an integer. GPI can therefore be seen as a quasi-phase matched four wave mixing (FWM) process. Many other FWM processes can coexist with GPI in a GRIN fiber, such as intermodal FWM [4], non-degenerate FWM between the pump and the first GPI band [5], or cascaded FWM of the first GPI band [6]. This makes experimental spectra very rich and complex, and it is often tricky to unambiguously identify the generated sidebands and their underlying generation mechanism. Usually, GPI sidebands are identified using relation (1) limited to second order dispersion ( $n = 1$ ) [2]. A few studies considered higher-order dispersion (HOD) [7], but its impact was not clearly illustrated. Here we show unambiguously that HOD plays a crucial role in the GPI process.

To illustrate this, we plot in Fig. 1 (a) and (b) the roots of Eq. (1) for a when all even dispersion orders are taken into account in solid lines, and when only second order dispersion is considered in dotted lines. This is done for two different parabolic refractive index profiles with a maximum refractive index difference between the core and the cladding of  $\Delta n = 20 \times 10^{-3}$  (Fig. 1(c)) and  $\Delta n = 33 \times 10^{-3}$  (Fig. 1(d)). For both cases the pump wavelength is 1064 nm.



**Fig. 1** (a,b) Frequency detuning of the GPI sidebands vs. core diameter from Eq. (1). (c-d) Measured spectrum after 1 m propagation. See text for details.

Two main conclusions can be drawn from these plots. First, for each value of  $k$ , two solutions appear for a given core radius when HOD is taken into account, while there is only one with second order dispersion. Second, there is a core radius value (around 25  $\mu\text{m}$  in both cases) under which no GPI can be observed when HOD is taken into account. This threshold cannot be seen when only second order dispersion is considered. Experiments (depicted by markers in Figs 1(a) and (b)) were performed to confirm this. Typical experimental spectra are displayed in Figs. 1 (c) and (d), at low power (10 kW) in blue and high power (40 kW) in red. At low power, well isolated GPI sidebands can be easily identified and match the theoretical curves pretty well. At high power, we checked that additional sideband appearing do not originate from GPI, but rather from the other mechanisms listed above. An unambiguous identification of all spectral peaks observed in the experiment will be detailed during the conference.

## References

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