**Multi-orbital lattices based on photonic molecules**

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**ABSTRACT**

The development of the femtosecond laser writing technique has revolutionized the fabrication of waveguide arrays and photonic systems due to its simplicity and versatility. Different configurations on different dimensions are possible by simply codifying the X, Y and Z positions of single waveguides inside a glass-like material [1,2]. However, the natural vertical ellipticity of fabricated waveguides is a major challenge that can be overcome by, for example, tuning the vertical distances among the waveguides to compensate the coupling constants anisotropy [3]. However, when having the need of, for example, exciting higher-order modes (orbitals) on single waveguides, this orientation destroys the mode degeneracy. Vertically oriented states are the first ones obtained experimentally [4], and the available degrees of freedom for studying more complex lattice interactions [5] are simply reduced.



Figure. Left: SP Photonic lattice. Right: Output intensity after 20 mm of propagation.

In this work, we use the femtosecond laser writing technique to fabricate close waveguides, such that them can be treated as an effective “photonic molecule” [6]. We demonstrate that different higher order states can be excited depending on the excitation wavelength, and that the vertical restricted dipoles of single waveguides [4,5] can be oriented arbitrarily. This can be thought as a simple spatial rotation but has very important consequences when studying lattice dynamics on trivial and non-trivial configurations. To demonstrate this phenomena, we study different inter-orbital lattice geometries and show how the interaction between originally orthogonal states can induce effective magnetic fluxes that can control the light propagation on linear systems [see Figure]. Specifically, we study a one-dimensional alternating SP lattice and its excitation with a zero-momentum Gaussian beam and observe a maximum dispersion with two well defined escaping lobes. This is in sharp contrast to the dynamics found in standard 1D lattices, where for zero momentum the energy is not transported at all. We also found that for a non-zero detuning in between S and P states, the 1D lattice can be mapped onto a diamond lattice exhibiting flat band and topological properties, which strongly affect the dynamics of this otherwise trivial lattice.

**Keywords:** Femtosecond-written waveguides; Photonic Lattices; Topological Edge States; High order modes; Effective magnetic fields.

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