One dimensional SP lattices based on Photonic Molecules

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Introduction

The femtosecond laser writing technique has revolutionized the fabrication of waveguide arrays and photonic lattices inside a glass sample due to its simplicity and versatility [1]. However, the vertical ellipticity of fabricated waveguides is a major challenge for studying more complex interactions on lattices [2]. When having the need of exciting different modes (orbitals) on single waveguides, this vertical orientation destroys the degeneracy and vertically oriented states are the ones obtained experimentally [3].

In this work, we use the femtosecond laser writing technique and study the effect of writing two closely spaced waveguides, such that them can be treated as an effective wider waveguide or "photonic molecule" [4] and put them together in an alternating SP lattice configuration.
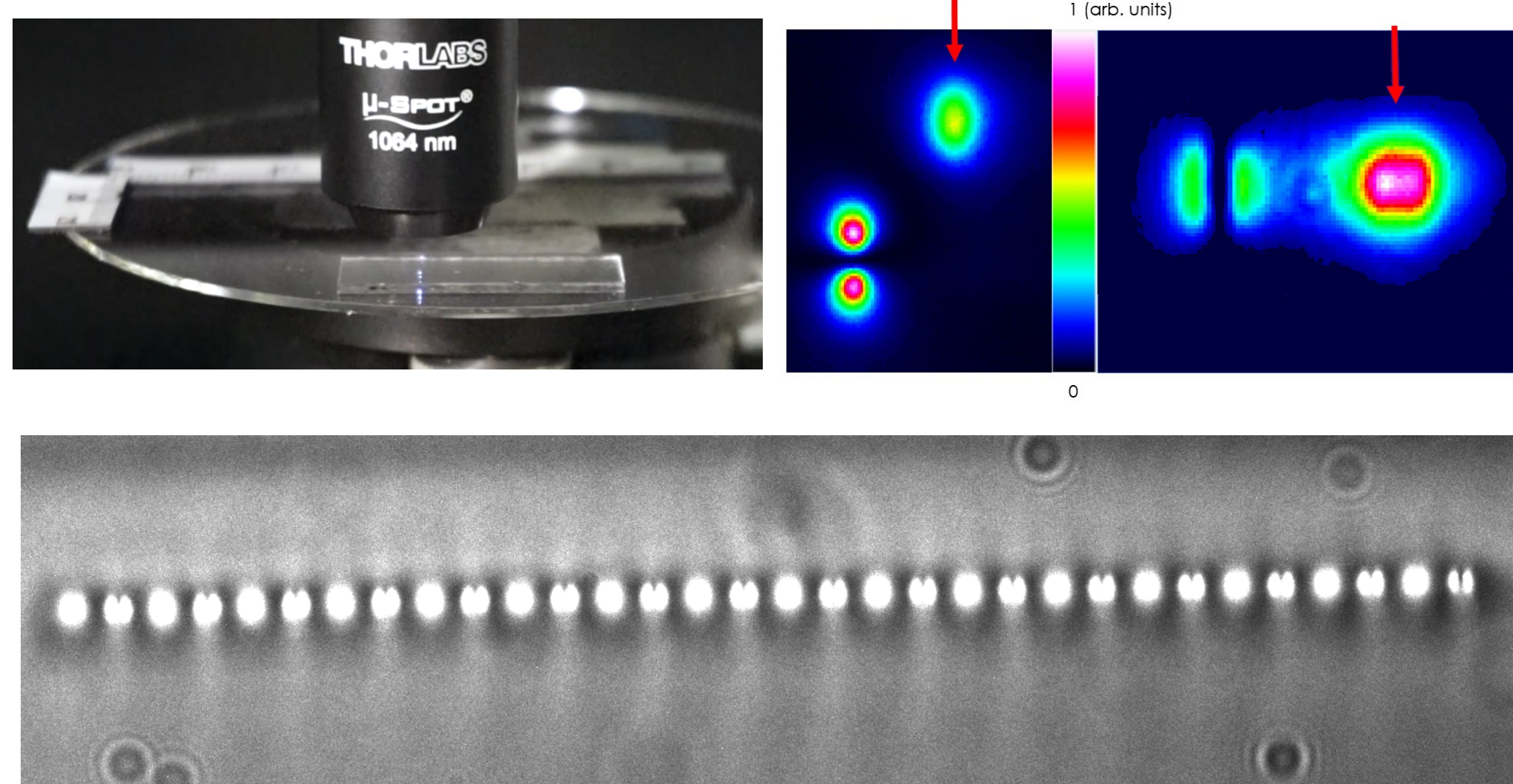

Fig. 1: a) Femtosecond laser focused inside a borosilicate wafer. Experimental images of b) SP couplers in both atom-like and molecule-like schemes and c) White light microscropic image of fabricated 1D SP lattice..

Results

By employing reasonable values for NNN couplings, we can replicate the phenomenological behavior observed in both wavelength scanning and SLM excitation techniques. To determine stationary solutions of equation (1), we plot the system's eigenvalues as a function of the detuning constant and calculate the participation ratio of the corresponding eigenvector $u_{\vec{n},\lambda}$ using the formula $R = \left(\sum_{\vec{n}} |u_{\vec{n},\lambda}|^2 \right)^2 / \sum_{\vec{n}} |u_{\vec{n},\lambda}|^4$.

We conducted a z-scan of a lattice with a separation distance of 30 μm and adjusted the fabrication power beforehand to achieve $\Delta\beta \sim 0$ for the SLM setup 730 nm wavelength.
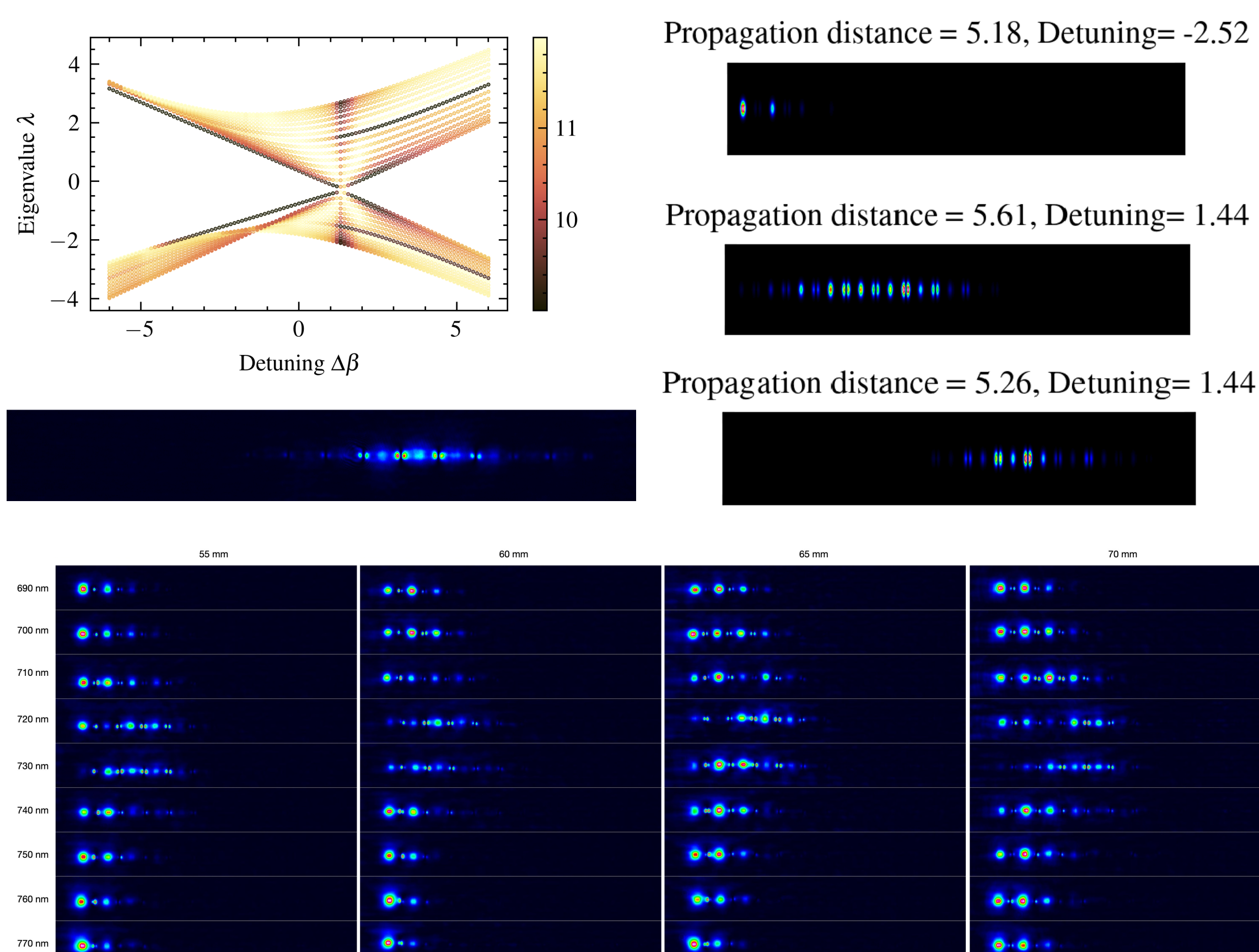

Fig. 2: a) Numeric bands of the system b1)-b3) Edge single-site excitation that emulates results in c) and d) c) Right edge dipole SLM excitation. d) Wavelength and z-scan of left edge ground state excitation.

Methods

We can apply Coupled Mode Theory to the system due to the strongly localized mode profile of single photonic molecules, which results in Discrete Schrödinger-like Equations (1) for the envelopes of the mode profiles. For simulations we consider interorbital coupling $C_{SP} = 1$ and take into account next-nearest neighbors (NNN) $C_S = 0.2$ and $C_P = 0.5$ while we sweep over the detuning value $\Delta\beta \equiv \beta_P - \beta_S$.

$$-i\frac{du_{\vec{n}}}{dz} = \beta_{\vec{n}} u_{\vec{n}} + \sum_{\vec{m}\neq\vec{n}} C_{\vec{n},\vec{m}} u_{\vec{m}}$$

$$(1)$$

We employ a blaze grating Spatial Light Modulator (SLM) technique to induce the dipole-like mode, enabling precise replication of the π-phase difference between the two dipole lobes. For Supercontinuum laser excitation and wavelength scanning, we use a simplified setup.
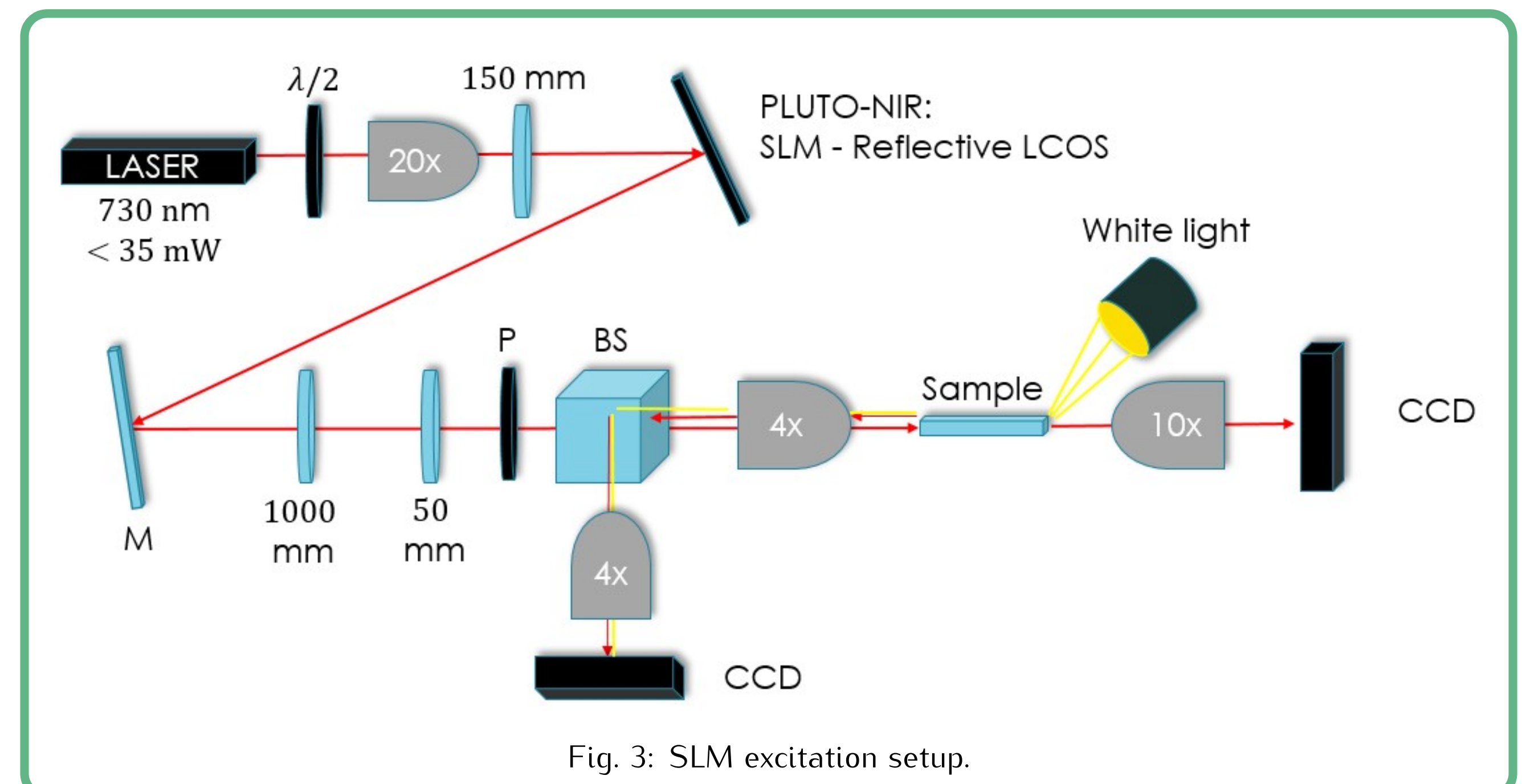

Fig. 3: SLM excitation setup.

Conclusions and Future Work

The addition of NNN couplings improved the agreement of the discrete model with experimental edge state formation, while the photonic molecule approach added complexity to an initially straightforward system. However, there is still room for improvement in tuning the detuning and coupling constant values.

Exploring the reconstruction of the system's dispersion relation by adjusting the momentum of a plane wave-like condition using the SLM setup would be an intriguing avenue for further investigation.

Acknowledgement

References

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