Illustrative Examples

Capturing images by adjusting the wavelength of a tunable laser

This experiment analyzes how the modal distribution at the output of an LPFG-based modal converter would change as the laser wavelength was varied. Specifically, how the modal distribution at the output would be affected by the laser wavelength while the temperature remains constant ($T_{room} = 21.65$ °C). This goal was achieved by first turning off the power meter modulus from the UI and then turning on the SWIR camera modulus, (see Fig. 1). The camera also had a lens-based imaging system to allow for image magnification and intensity distribution analysis. A polarization control was added to the input to study how the modes responded when the polarization of the light injected into the input of the modal converter was changed from 0° to 90°.

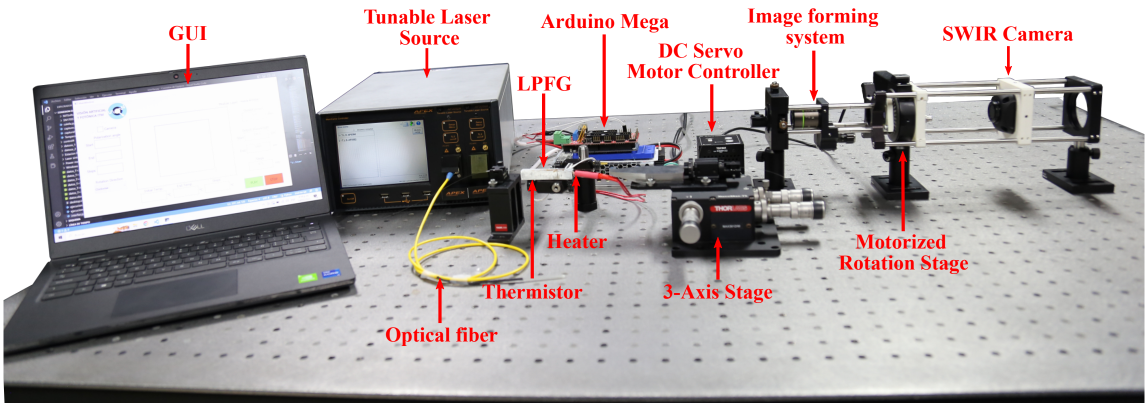
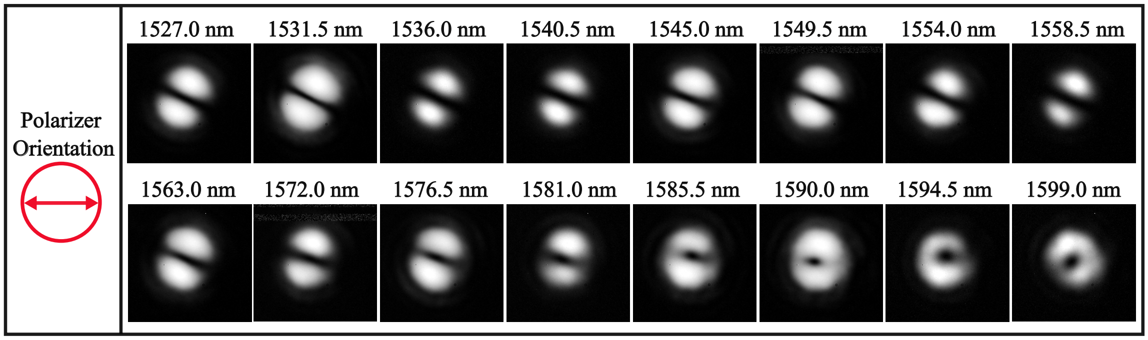


Fig. 1: Experimental setup to obtain images of the modal distribution at various wavelengths.

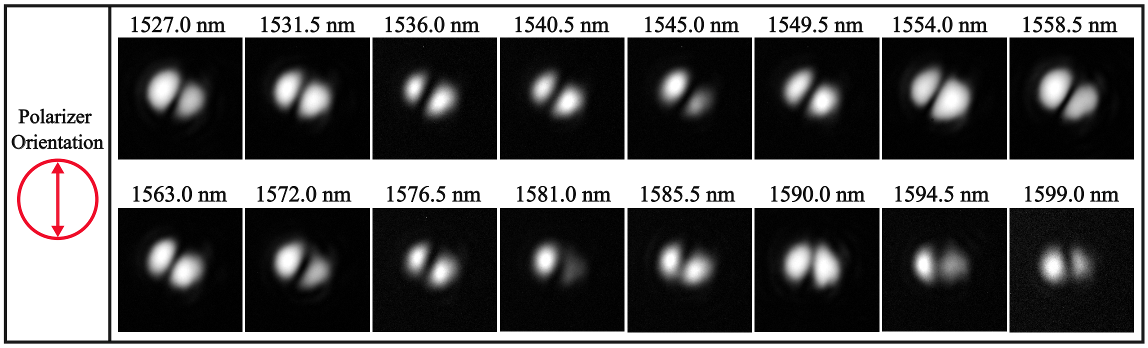
To start the experiment, the Enable Camera button, located in the upper-left corner of the UI, must be activated. This triggers the software to call the Image Module, which displays the recorded images in a new window. Next, the power and wavelength ranges must be entered through the GUI. In this experiment, an input power of 13 dBm was selected, and the wavelength of the AP3350A laser source was varied from 1527 nm to 1558.5 nm with a constant step of 0.5 nm. Additionally, the rotation stage, located in the upper-left corner, was activated and set to work only from 0° to 90° with steps of 90°. Finally, the mode was chosen for the analysis.

First, the LP_{11} mode, which presents a two-lobe intensity pattern, was chosen for analysis, and the results obtained when the light is injected with a polarizer orientation of 0° are shown in Fig. 2a. From these captures, it is possible to demonstrate a strong dependence of the modal distribution on the laser source wavelength. In fact, the results reveal a variation of the initial mode distribution, i.e., from LP_{11} mode at 1527 nm to another transition mode at 1599 nm. The same analysis was carried out when the light was injected at 90°, as is illustrated in Fig. 2b. In this case, a small variation was obtained in the modal distribution, however, the application allows for the record to be obtained under different conditions without problems.

By rotating the polarization direction of the polarizer, which is marked with a double-headed arrow indicating the transmission direction, two-lobe intensity patterns can be observed.



(a)



(b)

Fig. 2: Images of modal distributions taken at different wavelengths when light enters the mode converter: (a) Light injected at 0°. (b) Light injected at 90°.

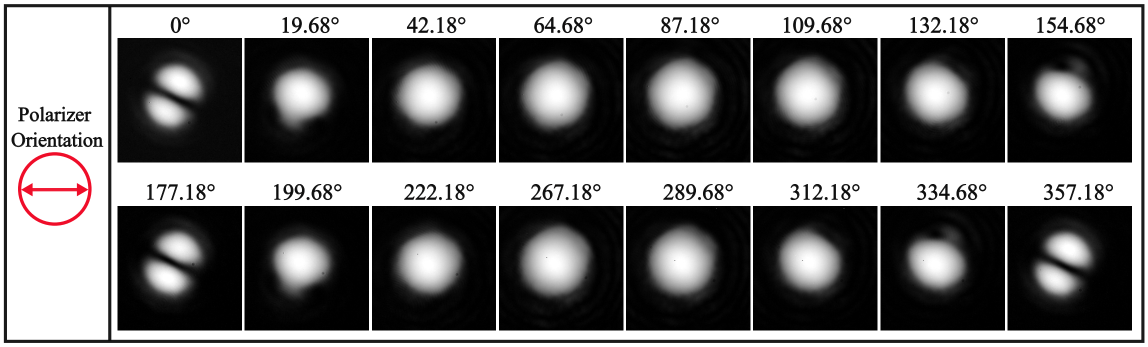
Capturing imaging by adjusting the polarization of light at the output of the optical fiber mode converter

In the third experiment, the proposed software is used to evaluate the LPFG-based mode converter device when the rotational stage is used to control the light polarization at the device's output. This evaluation is carried out to determine whether or not the polarization of light can be controlled by the rotational stage. As previously mentioned, it is necessary to turn on the camera by pressing the button that is in the upper-left corner of the UI. In addition, the laser source is required, so the AP3350A laser source is selected from the drop-down menu located in the top right corner of the screen. Finally, the rotational stage is positioned at the output of the system. After that, the check box that works as a trigger for this component must be selected in the UI.

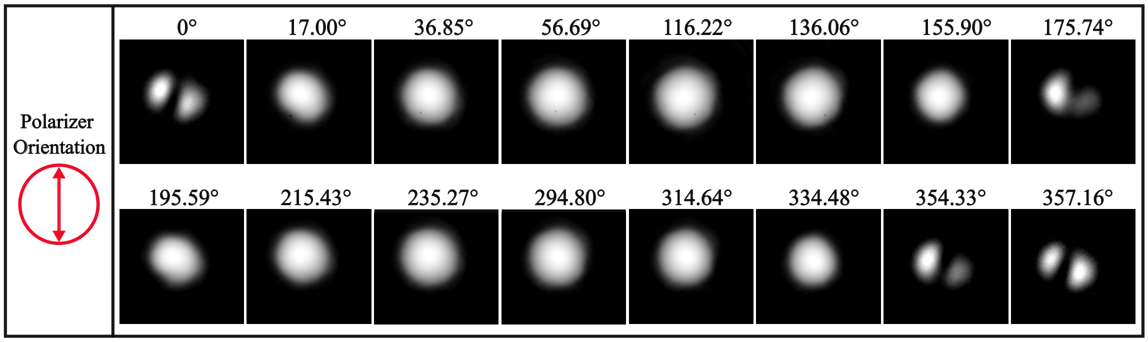
In this specific case, it was determined that a constant value for the wavelength of the laser diode should be used, so it was set at 1550 nm. Likewise, a linear polarizer was placed in the rotational stage at the output of the system and is set to rotate from 0° to 360° with 3° step. Finally, the clockwise direction was chosen from the UI.

The Fig. 3a shows the images captured when light is injected at 0° in the mode converter device while rotating the rotational stage at the output. The obtained results reveal that the modal distribution presents strong changes. In fact, it is possible to demonstrate that the mode at 0° changes to the mode when the analyzer (polarizer at the output) is placed at 87.18°. Moreover, the results show cyclic behavior in this device when the analyzer continues to rotate up to 360°.

The same experiment was carried out when the light was injected at 90° into the modal converter. The results that were collected are summarized in Fig. 3b. The capability of the developed program can again be demonstrated as a consequence of both sets of findings; however, in this particular instance, it was able to control the rotatable stage and the laser source as well as the camera to capture the modal distribution of a mode converter in real time.



(a)



(b)

Fig. 3: Images of t modal distributions captured at various angles of the analyzer when light is injected into the mode converter: (a) Light injected at 0°. (b) Light injected at 90°. All images were captured at a constant wavelength of 1550 nm.

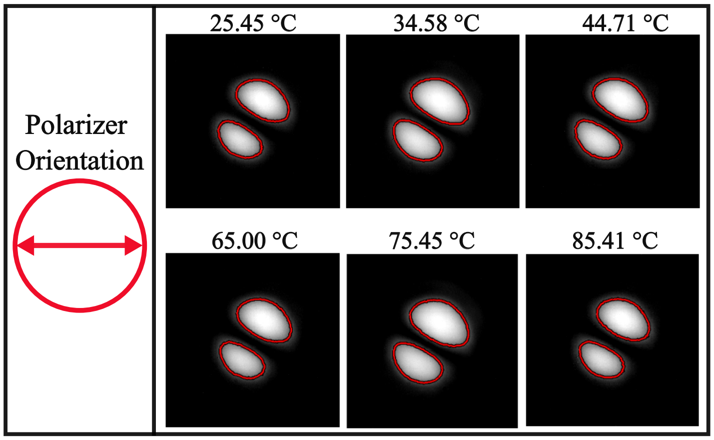
Capturing imaging at different temperatures

A laser source, a camera, and temperature control are the three components that make up the experimental setup that is employed in this experiment,(see Fig. 1). The "Enable Temperature" button is used to turn on the temperature control to trigger the execution of the Temperature_Control.py module and take pictures under a variety of temperature settings. In this particular case, the AP3350A serves as the laser source. It generates laser light with a stable wavelength of 1550 nm, which is then injected into the modal converter.

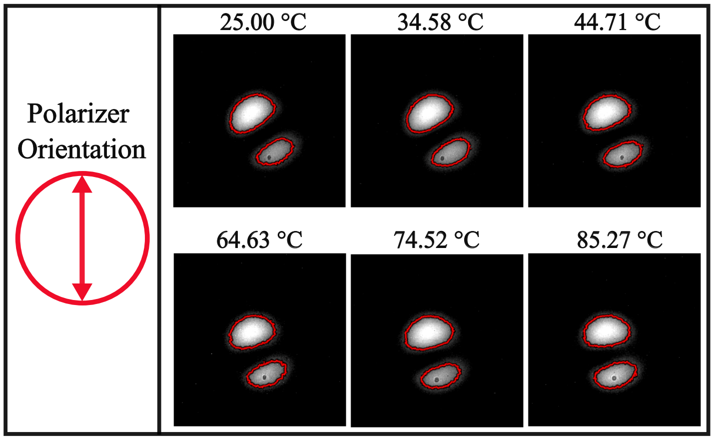
For this experiment, the setpoint temperature ranges from 25 °C to 85 °C, with a step of 5 °C. It is a function of the WiDy SWIR 640v camera to take pictures during this temperature range. However, pictures are only taken when the temperature is within 0.5 °C of the setpoint and after a period of 60 seconds has elapsed since the beginning of the stabilization process. Consequently, images are not taken in real time; rather, they are captured in discrete bursts.

The phase of the light shifts as a result of temperature changes, as can be seen when analyzing the images of these photos after they have been collected. This, in turn, causes a slight rotation in the intensity profile of the propagation modes that are transmitted through the LPFG-based modal converter. This rotation is more pronounced in the LP11 mode. The LP_{11} mode for two different polarizer orientations at the input, 0° and 90°, are illustrated in Fig. 4a and Fig. 4b, respectively. It is easy to see that as the temperature rises, there is a slight rotation in the intensity profile of the mode that can be noticed. To draw attention to this alteration, the figure features a red highlighting of the mode shape.

The experiment further demonstrates that the created interface is capable of successfully controlling image acquisition experiments concurrently while subjecting the optical fiber to controlled temperature fluctuations. This capability was successfully demonstrated by the experiment. This allowed precise control over the experimental parameters, removing any potential impact that could have been caused by the presence of an user in close proximity to the setup, which could have caused fluctuations in temperature and affected the accuracy of the readings. Likewise, the created interface provides a stable and effective means of running the experiment, allowing the temperature to be accurately managed and images to be acquired automatically. This feature paves the way for new options to conduct experiments in a controlled and methodical manner, facilitating accurate data collection and analysis. Researchers and scientists can explore the effects of temperature on the behavior of propagation modes in the modal converter with greater accuracy and repeatability thanks to the interface, which acts as an important R&D tool.



(a)



(b)

Fig. 4: Images of the LP_{11} modes in their two polarizations at various temperatures. (a) Polarizer set to 0°. (b) Polarizer set to 90°. The images illustrate that the intensity profile of the LP_{11} mode rotates as a result of temperature changes.

Illustrative Video

The first segment of the video demonstrates how to use the GUI to acquire images with various polarization angles at the output of the investigated optical device, in this case the LPFG-based modal converter. The program allows the user to configure the laser's operating wavelength and optical power. On the left-hand side the acquired images are displayed, while the compiler terminal shows relevant data, such as the number of acquired images, their size, the wavelength value selected by the user, and the angle rotated by the rotation station. On the right-hand side the rotation of the rotating station is depicted.

In the second segment of the video, the implementation of a GUI for imaging the output of an optical fiber at various wavelengths is demonstrated. The captured images are displayed on the left side, while the compiler terminal displays relevant information such as the number of captured images, their sizes, and the wavelength values associated with each image. As the wavelength value is altered, the tunable laser display is shown in the upper right quadrant.