Experiment 4:

Fiber Optic Sensors

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Abstract

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1 Experiments

1.1 Proximity Sensor

Task:

Fix the 777-1 dual fiber bundle into the collar as shown in the figure. Gently tighten each set screw. Do not over tighten. Illuminate one end of the dual fiber bundle with a *HeNe* laser. This sensor can also be constructed using a white-light source if you have a high-power lamp which can be focused onto the end of the fiber bundle.

For our experiment we used a *HeNe* laser aimed at a dual fiber bundle, using lens holders we stood the fiber right at the height of the laser.

Task:

Place the post with the common end of the fiber bundle into this holder and fix it to translation stage and. Set up a card so that the *HeNe* output of the fiber bundle shines on the card or mount the translation stage so that the output shines on a wall. In either case, the fiber bundle needs to be mounted so that it is able to actually make contact with the surface to be measured.

We did this by taping down a ruler to the table so that we could measure the distance from the built screen and the fiber end. The final end was tightened into a lens holder so that we could put the power meter close and take power measurements.

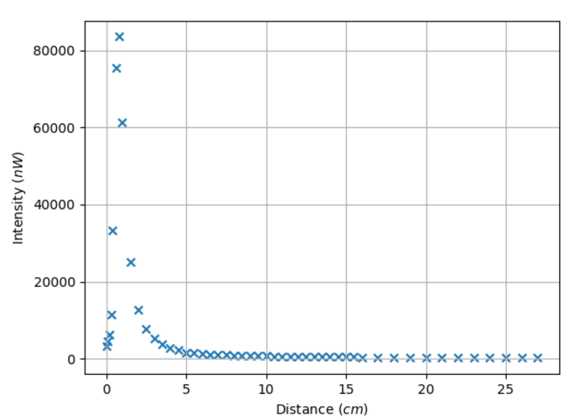
Task:

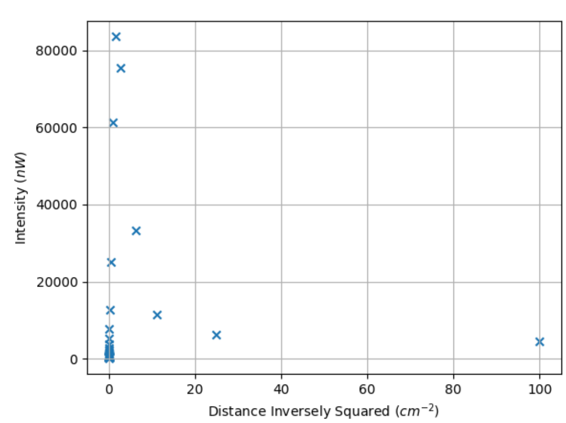
Light reflected by the surface being monitored will be reflected back into the fiber bundle and will go to the second single end. Mount this end in a post holder and couple the output light onto the detector of the Power Meter

We used a wooden screen with a piece of paper taped on it. We put the ruler zero at the post center, knowing that the fiber was a little bit further. We took the data from the furthest point to the closest, and when the screen was right at the fiber we measured the distance from the ruler zero to that point, substracting it from all the datapoints previously taken.

Task:

Measure the reflected output as a function of distance, d, of the surface of the common end of the bifurcated fiber bundle from the monitored surface. Also plot power as a function of $1/d^2$.



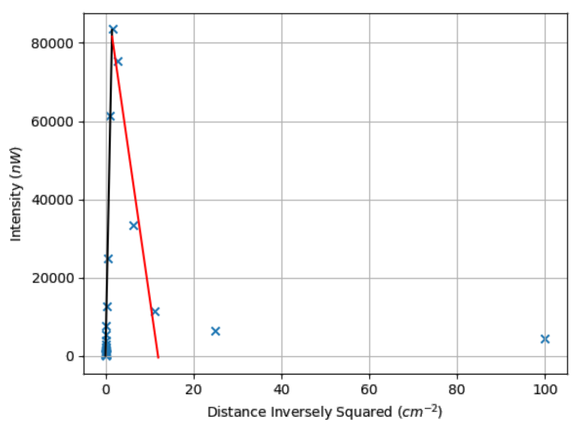


Task:

Find the point where a linear $1/d^2$ dependence begins. This is the distance at which the finite diameter of the fiber core is no longer significant in determining the amount of reflected light accepted by the fiber bundle. Why does the amount of reflected power accepted by the fiber bundle drop from a maximum as you get very close to the surface? (**Hint**: Draw the light cone from the fiber bundle incident on the surface being monitored and the cone of acceptance of the neighboring fiber which detects the light. Vary the distance between the fiber end faces and the reflecting surface.)

Estimate the positional resolution of this sensor.

By looking at the two previous plots we can see how clearly there is a change in dependence. If we fit the first part of the inversely quadratic plot, we can see how it is clearly correspondent. However, the second part of it is not, when we get further than 12 cm the linearity disappears. This is probably because the reflections of the screen are negligible in comparison to the lighting of the experimental room. From the plots we can extrapolate the $1/d^2$ dependence to only truly work from the fiber opening to around 12 cm, having a turning point at 1.7 cm from the fiber.



But why do we observe this turning point? This phenomenon can be explained by the concept of numerical aperture, a measure of the range of angles over which the system can accept or emit light. When the screen is far from the fiber end, the light cone from the fiber bundle incident on the surface is wide, and the reflected light also forms a wide cone. This wide cone of reflected light can be captured by the fiber bundle, leading to a high power reading at 1.7 cm.

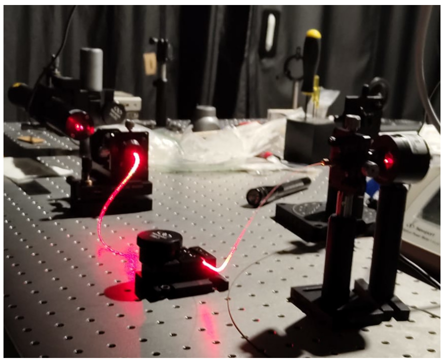
As the screen gets closer to the fiber end, the incident light cone becomes narrower. Initially, this leads to an increase in power because the light is more concentrated. However, when the screen is very close to the fiber end, the incident light cone is so narrow that the reflected light cone exceeds the acceptance angle of the fiber bundle. This means that some of the reflected light is not captured by the fiber, leading to a decrease in the measured power.

1.2 Microbend Displacement Sensor

Task:

We can use the mode scrambler as an example of a displacement sensor. Rotate the knob on the scrambler to fully separate the corrugated surfaces

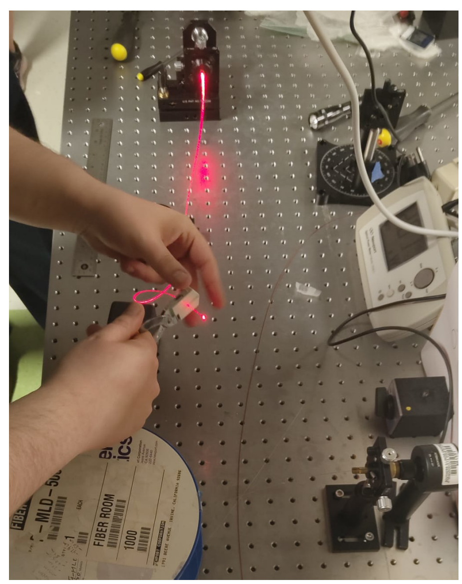
Launch light into a segment of Multimode fiber using the He-Ne laser and the F-916 coupler. The laboratory set-up for this sensor is shown in the figure.



For this section we reused the fiber that was used on Experiment #8 as we can see on the picture. The laser was focused into the fiber optics and then passed through the scrambler. Finally the fiber was terminated into a power meter. We can see the fiber as red because of all the leakage that's happening throughout its length. This intensity will diminish after the scrambler once we start bending the fiber with it. Both of the ends of the fiber had to be properly treated so that they are clean and straight, according to the methodology described in previous experiments.

Task:

Place the jacketed fiber in the slot between the corrugated surfaces the rotate the knob until the corrugated surfaces just contact the fiber. Note the knob position.
Each major graduation on the knob represents a 25 μm displacement. The smaller graduations mark 12.5 μm displacements.

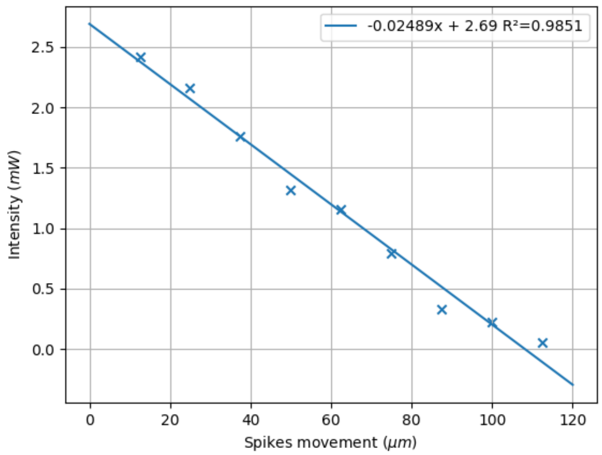


As we have just described, we can see in this picture how the optic fiber was treated moving from the previous experiment, the coating was being removed at this stage. The knob of the scrambler moved two pair of teeth that put the fiber into a tight angle. By doing so, most of the leakage was now happening at that point. We could tell that because the leaked light intensity at the scrambler increased.

Task:

Record the output from the fiber as a function of displacement. The fiber has a soft buffer, so some period of stabilization may be needed after you set the displacement for the transmitted power to come to equilibrium. In an actual sensor system, the knob-controlled displacement would be replaced by having the corrugated surfaces attached to two surfaces whose relative position is to be measured.

In fact, several seconds were needed after taking a measurement to ensure stability in the reading of the power meter. Our starting baseline power was 2.49 mW. We took 9 points spaced 12.5 microns from each other.



As we can see on the data the tendency was quite linear, more specifically negatively linear. Our R^2 coefficient was quite acceptable reinforcing the interpretation of a linear correlation.

The OX axis represents the distance that the spikes moved when the knob was turned. The OY axis represents the intensity recorded by the power meter. Our baseline was recorded when the spikes were barely touching the fiber and the power meter didn't register any dip.

2 Addenda

LaTeX code that generates this document

PHOTONICS-LabRep9:fibsensor.tex

Python code that generates the plots and contains the data

PHOT-E9.py