Sensitivity of a tapered fiber optic displacement sensor with S-shaped structure

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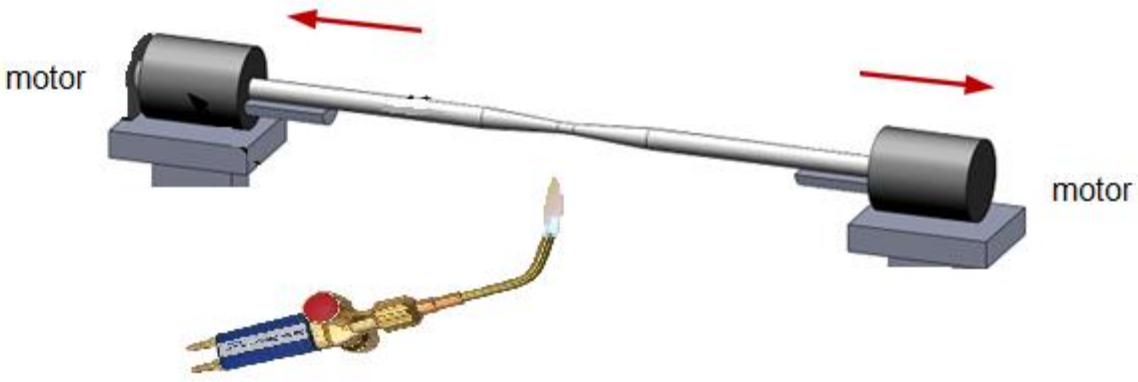
ABSTRACT

We present and analyze the transmittance characteristics of displacement sensors based on S-curved and tapered single-mode optical fibers. We compare the sensitivity of the S-curved tapered fiber sensor, with respect to the sensitivity of the tapered fiber without prior curvature. The results show sensitivities of up to 192 pm / µm for the S-type sensors relative to sensitivities of the order of 100 pm / µm for the simply tapered sensors.

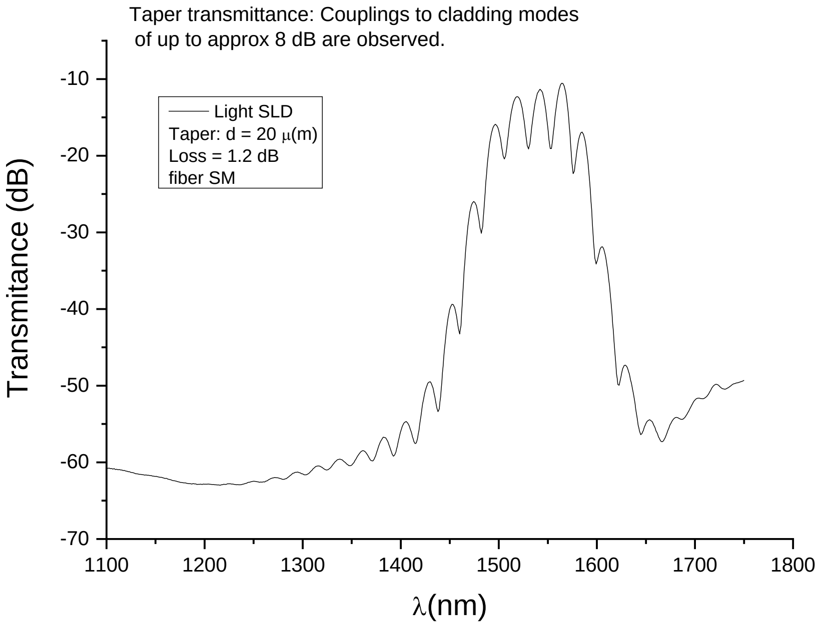


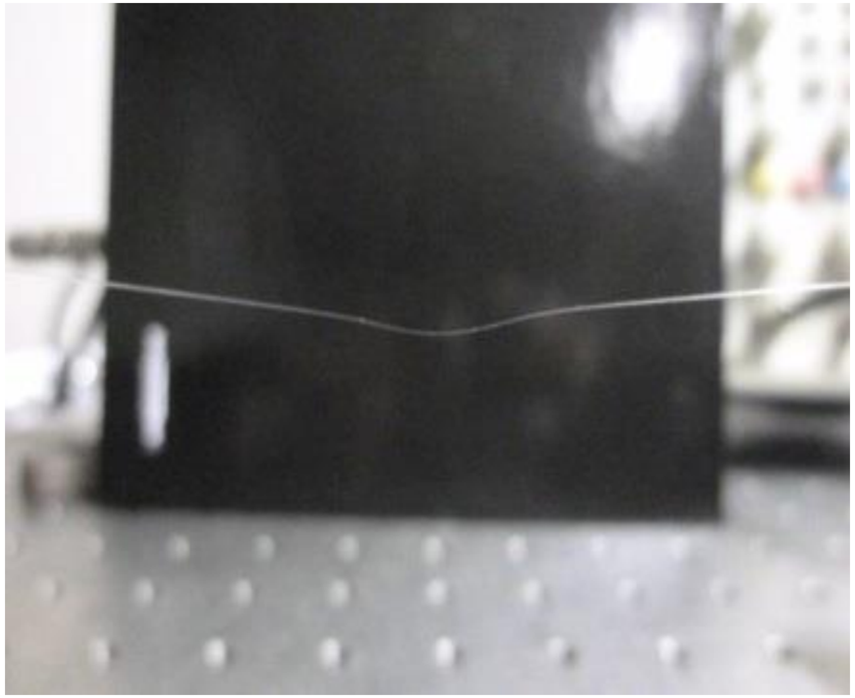
Biconical tapered fibers are prepared by heating and pulling the ends of the optical fibers reducing the diameter of the cladding (along with that of the core) to 30 µm in a tapered region of 10 mm in length.

By thinning the optical fiber, the light that is guided in the fundamental mode of the core is transferred to the fundamental mode of the cladding. For fiber diameters greater than 10 µm, the guidance in the core sheath is multimode and the progressive fiber tuning couples the angular symmetry modes LP01, LP02, LP03, LPon. When the tapered region is curved, there is also coupling with the odd modes (LP11, LP21, ...).

$$C_{nm;pq} = \int_0^{\infty}\int_0^{2\pi} \varepsilon_{pq}^{(i+1)}(r,\emptyset)\,\varepsilon_{nm}^{(i)}(r,\emptyset)\,r\,dr\,d\emptyset$$

$$C_{nm;pq} \neq 0 \quad \text{if } n = p$$
$$= 0 \quad \text{if } n \neq p$$

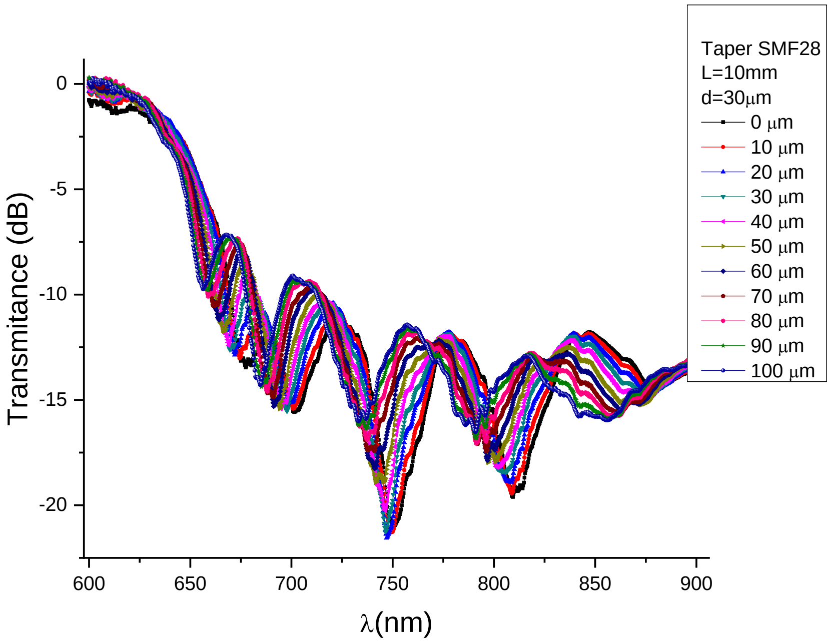


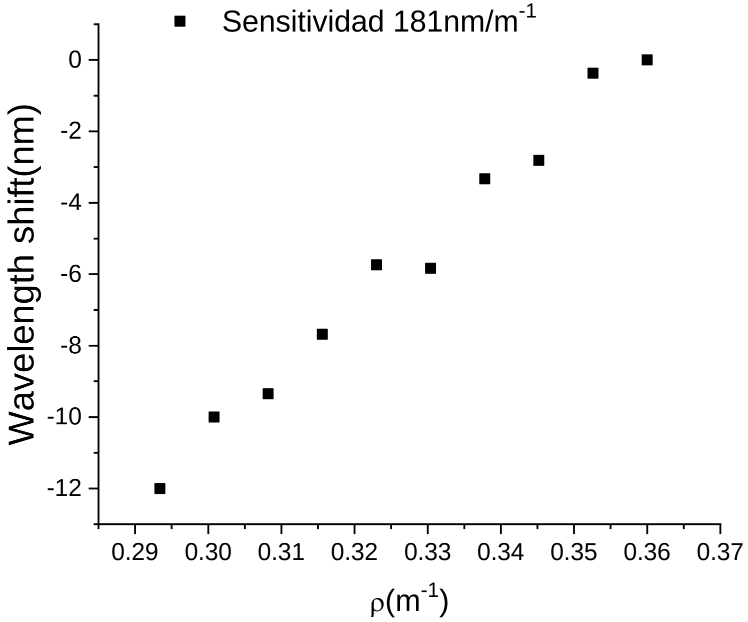


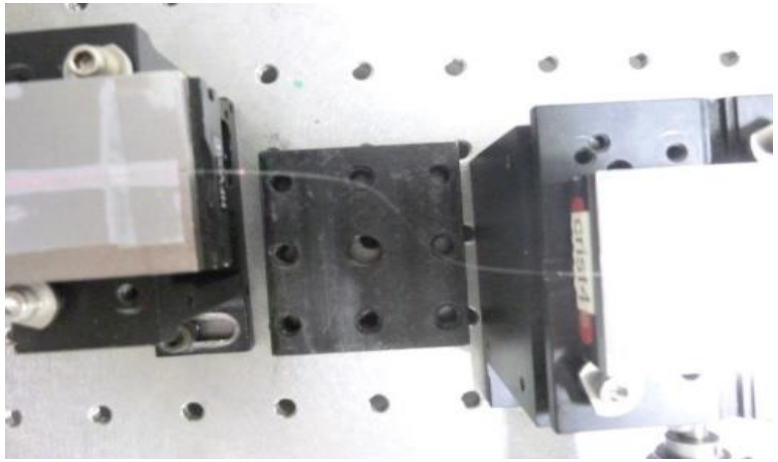
When the tapered fiber is curved, as shown in the figure, in addition to coupling between the radial modes LPom, it originates coupling to the non-symmetrical modes LP1q, and, in general, coupling between the modes LPnm and LPnq or LPn ± 1q being observed the appearance of deeper losses in transmittance.

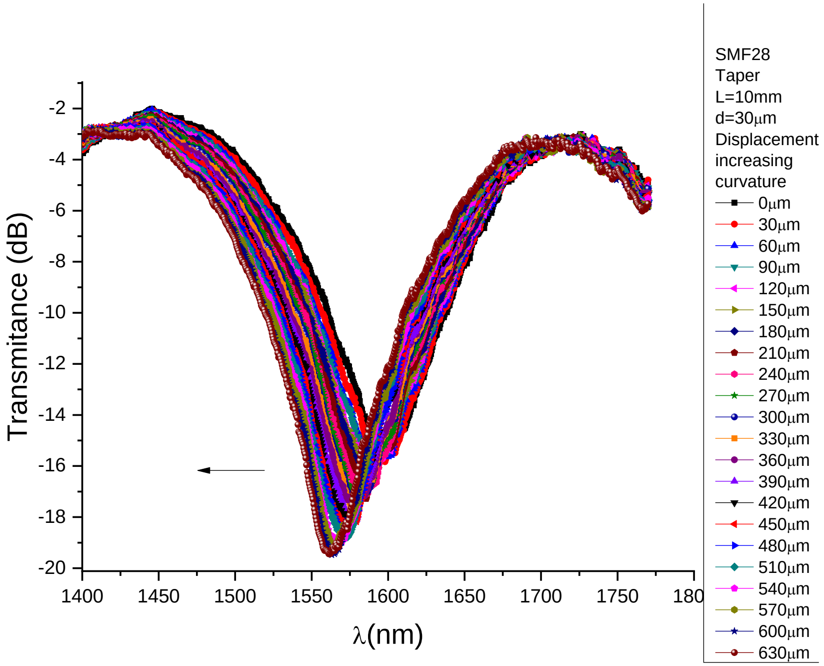
$$C^{\psi}_{nm;pq} = \int_0^{\infty}\int_0^{2\pi} \varepsilon^{(i)}_{nm}\, \varepsilon^{(i+1)}_{pq} \left[J_0\left(X^{(i)}_{nm} r\right) + 2jJ_1(X^{(i)}_{nm} r)\cos(\phi)\right] r dr d\emptyset$$

$$C^{\psi}_{nm;pq} \neq 0 \quad \text{if } n = p \text{ or } n = p \pm 1$$
$$= 0 \quad \text{otherwise}$$

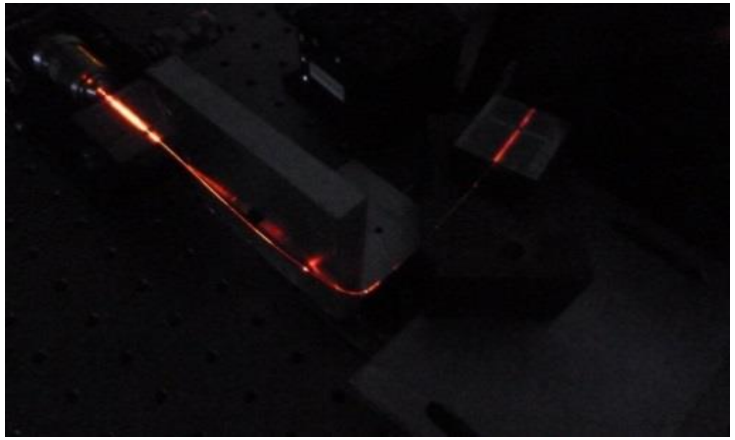

Taper SMF28
L=10mm
d=30μm
0 μm
10 μm
20 μm
30 μm
40 μm
50 μm
60 μm
70 μm
80 μm
90 μm
100 μm
Transmitance (dB)
λ(nm)
0
-5
-10
-15
-20
600
650
700
750
800
850
900

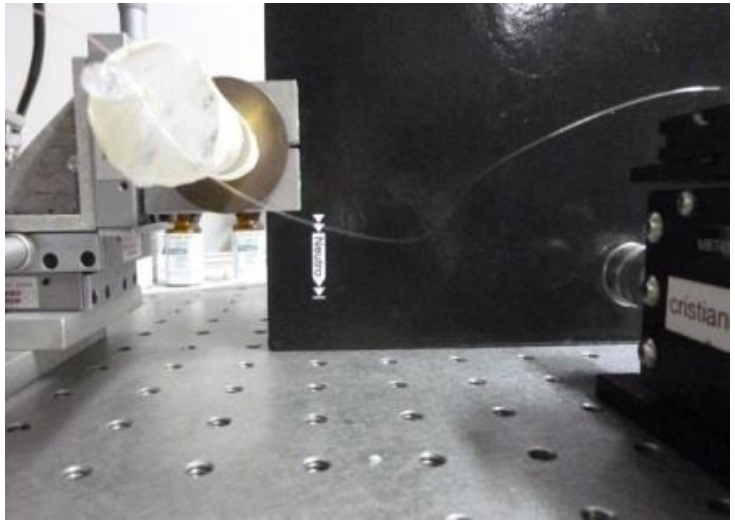

Sensitividad 181nm/m-1
Wavelength shift(nm)
ρ(m-1)
0
-2
-4
-6
-8
-10
-12
0.29
0.30
0.31
0.32
0.33
0.34
0.35
0.36
0.37





The number of minima in tapered fiber transmittance, as well as the depth of transmittance loss in decibels of these minima, vary as the shape of the fiber curvature changes. The sensor is more sensitive to curvature formed in the pre-taper region at the entrance of the fiber thinned.

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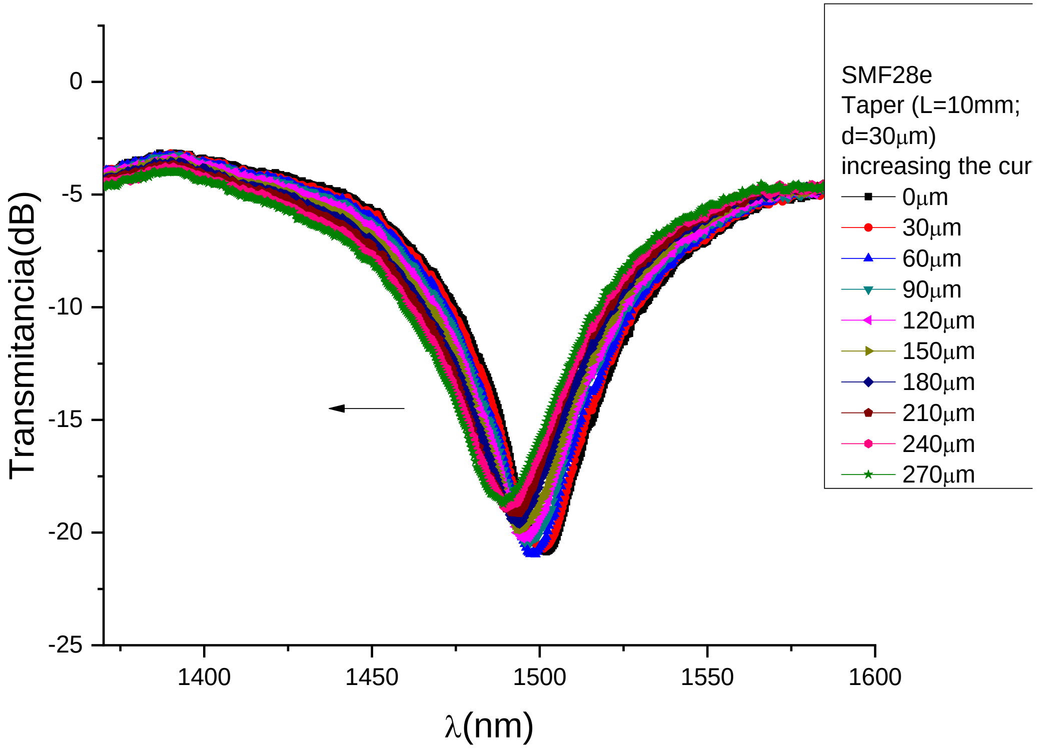
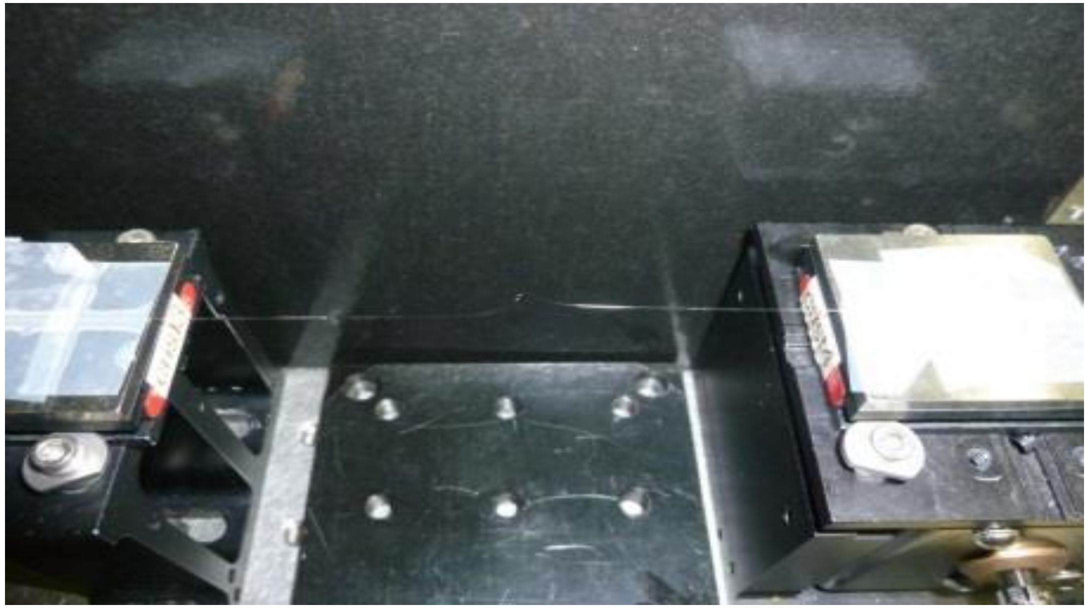
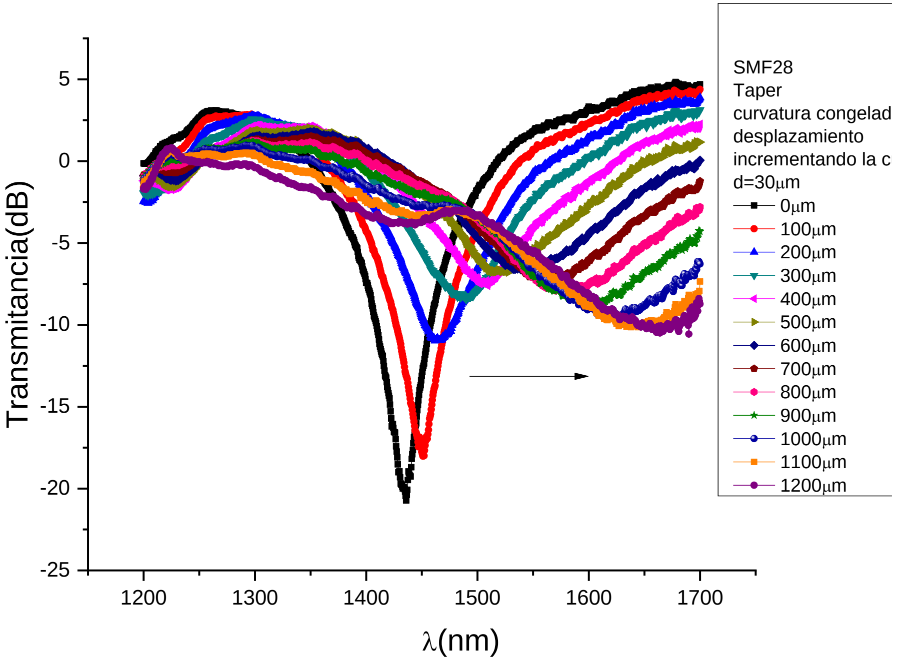
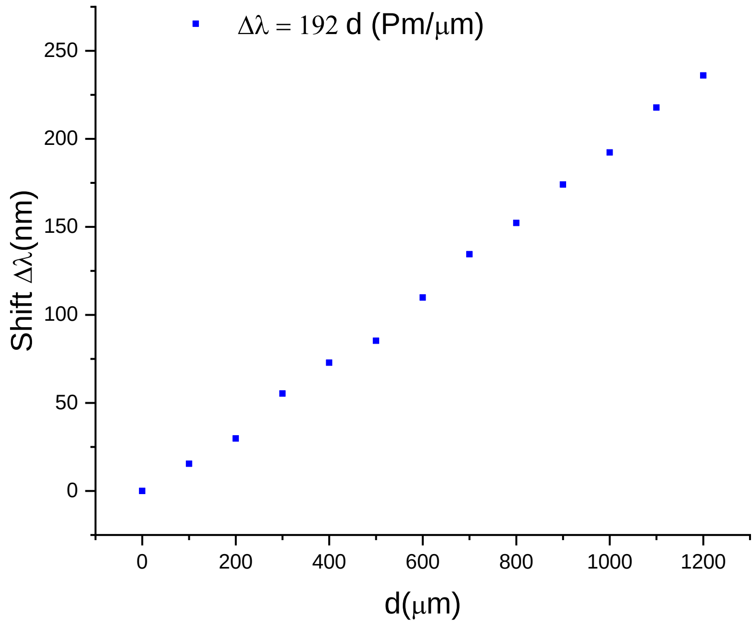

Transmitancia(dB)
0
-5
-10
-15
-20
-25
1400
1450
1500
1550
1600
λ(nm)
SMF28e
Taper (L=10mm;
d=30μm)
increasing the cur
0μm
30μm
60μm
90μm
120μm
150μm
180μm
210μm
240μm
270μm

Strong dependence of the sensor sensitivity to the initial curvature conditions of the fiber.

Taper with initial curvature "frozen"





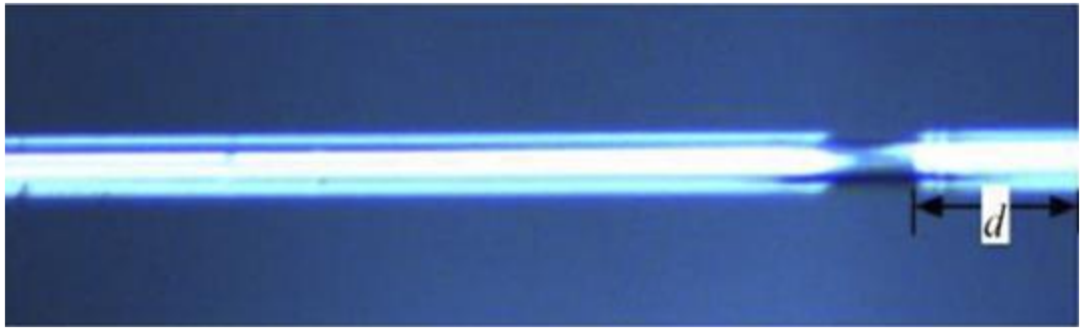


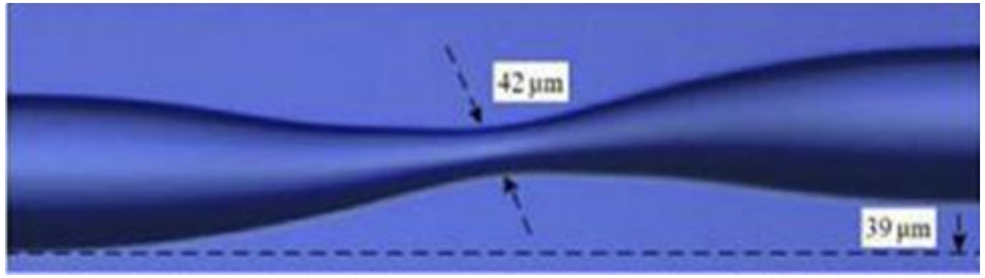
Displacement range: 0 to 1200 μm

Sensitivity: 192 pm/μm

Resolution: 10 μm (less than 1% of range)

Fabrication and sensing characterization of an S-tapered fiber probe





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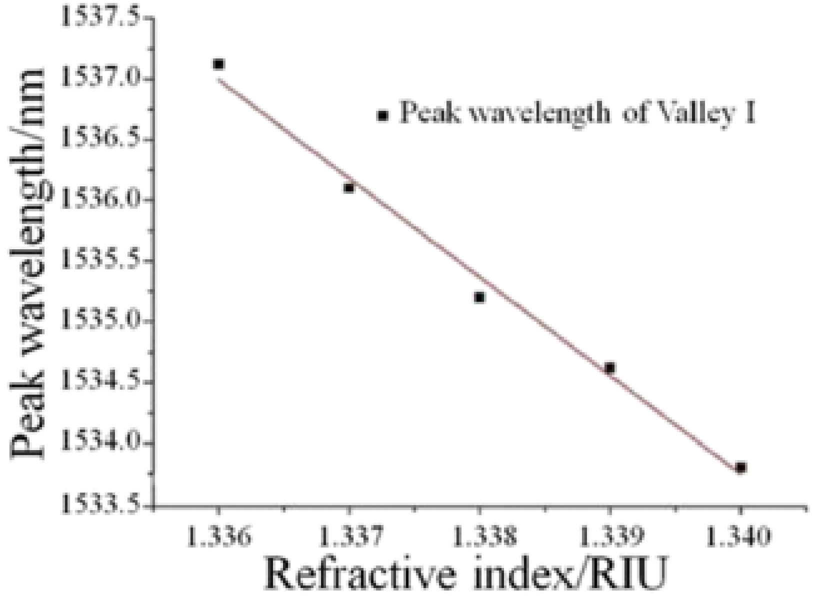

S-tapered fiber probe displays a RI sensitivity of 1242.9 nm/RIU in the RI range 1.336–1.340

CONCLUSIONS

This research shows that the range and sensitivity of displacement sensors based on tapered fibers strongly depend on the initial curvature geometry of the fiber, being able to increase the sensitivity of a sensor with curvature in S from 100 pm/μm to values of 192 pm/μm, as well as the range from 270 μm to values as high as 1200 μm.

MUCHAS GRACIAS POR SU ATENCIÓN !!