CHARACTERIZATION AND TESTING OF FIBER OPTIC CURVATURE SENSOR AS AN OPTICAL MODE CONVERTER FOR DEFORMATION MEASUREMENT

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ABSTRACT: **In this paper, a fiber optic curvature sensor (FOCS) implemented using plastic optical fiber (POF) with a sensitive zone is tested. Sensitive zone represents a V-shaped teeth which are etched into the fiber, in order to increase the sensitivity of the optical fiber to bending. Essentially, the measurement is based on detecting changes in the output intensity distribution depending on the deformation (curvature) of the fiber. Deformations are applied in both directions, meaning it was examined how the position of the sensitive zone on the fiber, whether it is on the concave or convex side of the bent fiber, affects the output signal.**

Measurement setup

- LED (650 nm) is used as a light source
- Mode converter is placed between the LED and FOCS in order to excite multiple modes
- FOCS is mounted on a thin metal beam firmly fixed at one end
- Bending deformation of the metal beam is introduced by deflecting the free end of the beam using precision translation positioner
- Output intensity distribution is recorded using a CCD sensor
- Signals from the CCD are further processed in the LabVIEW software package

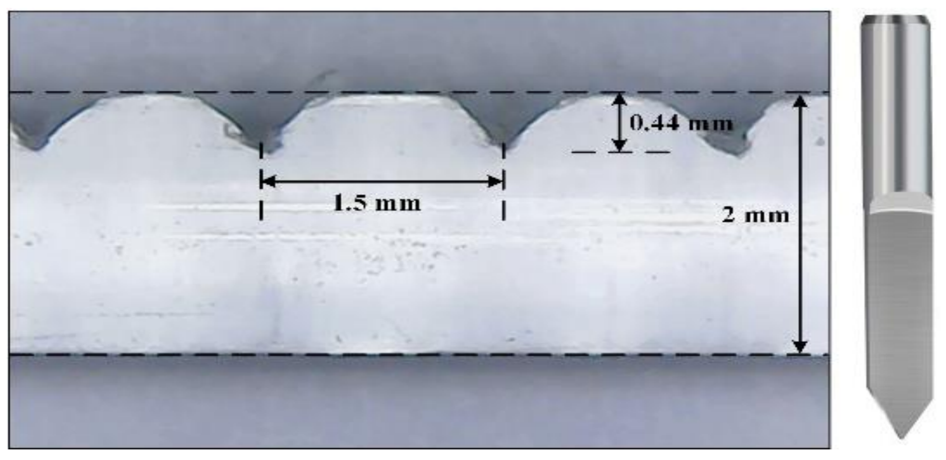

Fig. 2. V-shaped teeth that form the sensitive zone and 60-degree machine cutter

In Fig. 2. the photo of the FOCS sample that is used as device under test in this work is given. Sample is fabricated by mechanical cutting of teeth on the 2 mm POF. Total of 50 teeth with spacing of 1.5 mm and depth of approximately 0.4 mm is machined on top of the 1 m long POF.

Sensing principle

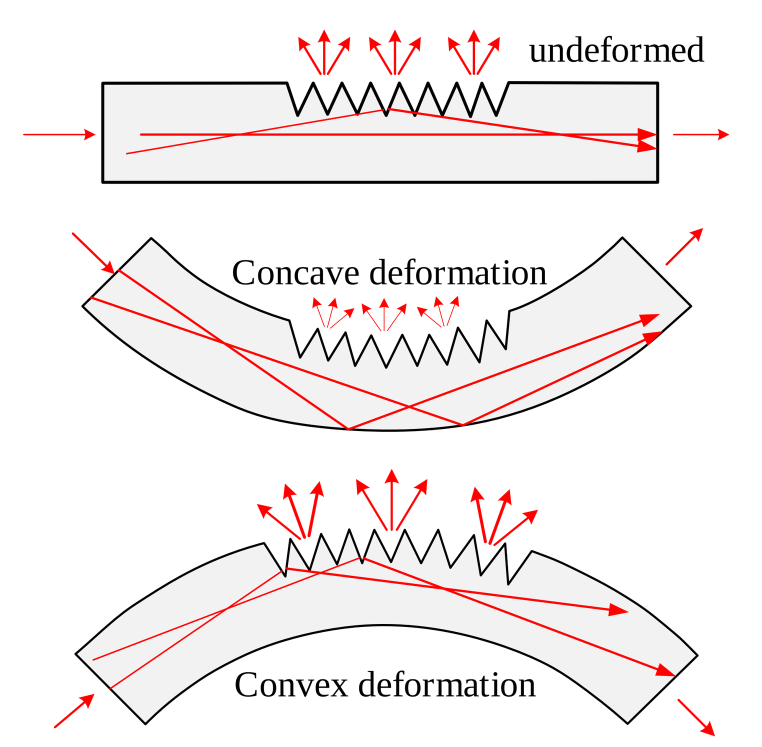

Fig. 3. Illustration of sensing principle FOCS

1. **Negative bending – concave deformation** → fewer light rays interact with sensitive zone → **increasing** output light intensity
2. **Positive bending – convex deformation** → more light rays interact with sensitive zone → **decreasing** output light intensity

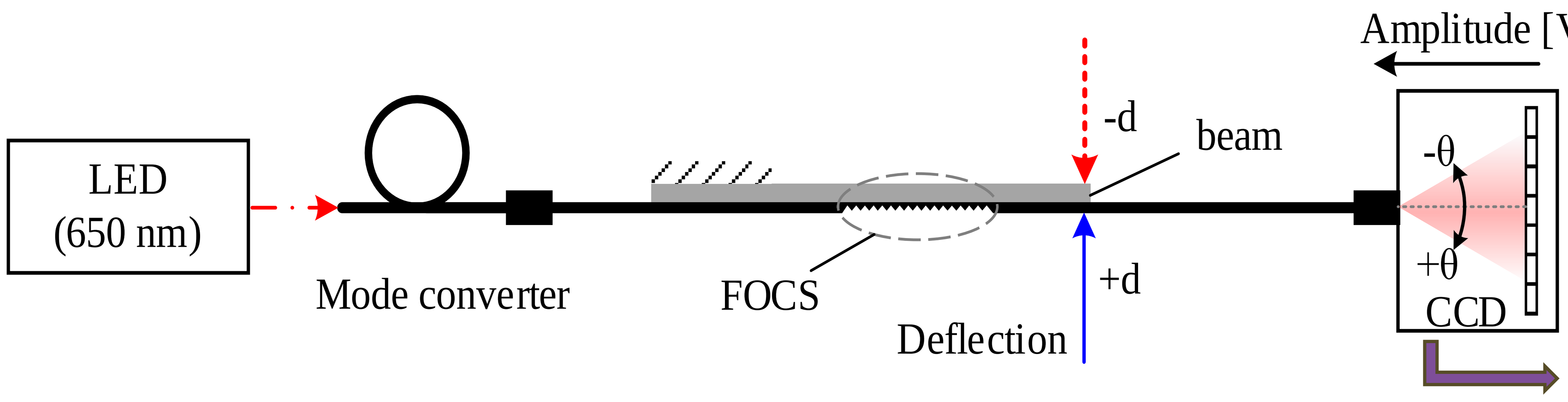

Fig. 1. Experimental setup for the characterization and testing of the proposed FOCS sensor

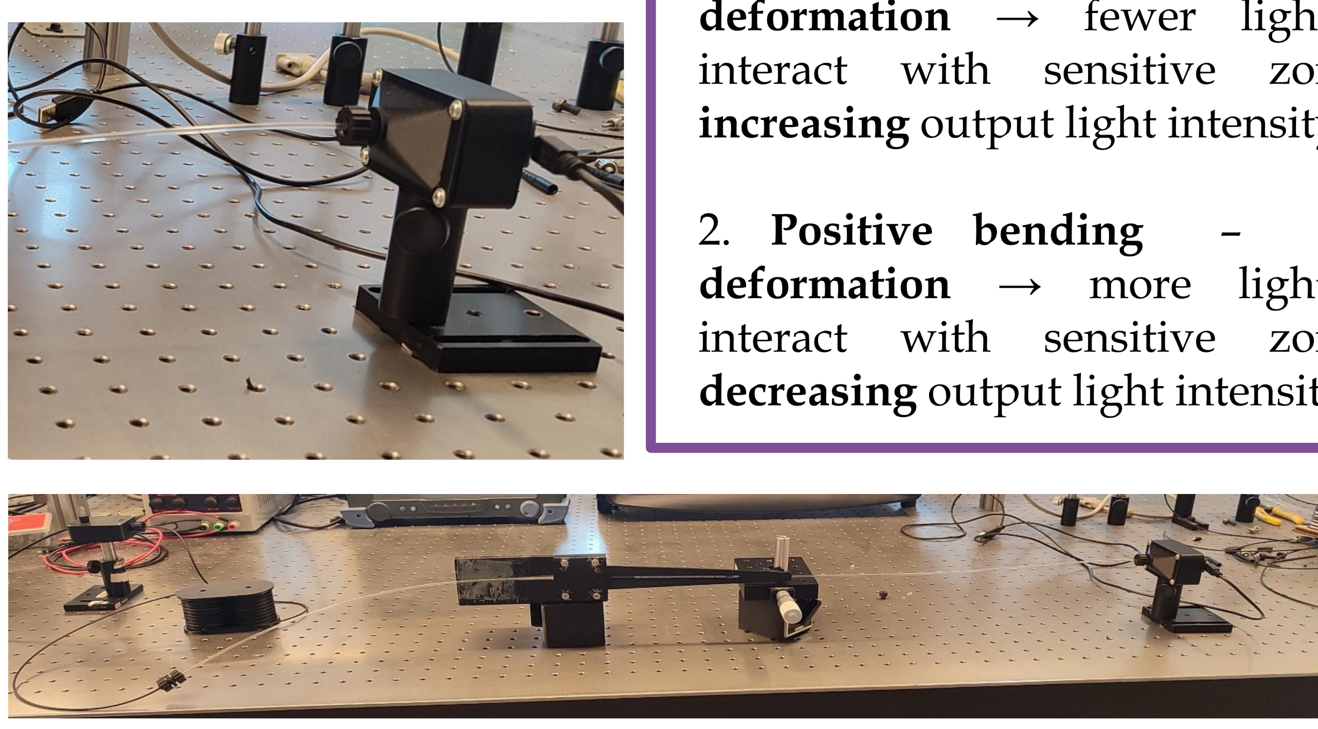

Fig. 4. Experimental setup in the laboratory

Measurement results and conclusion

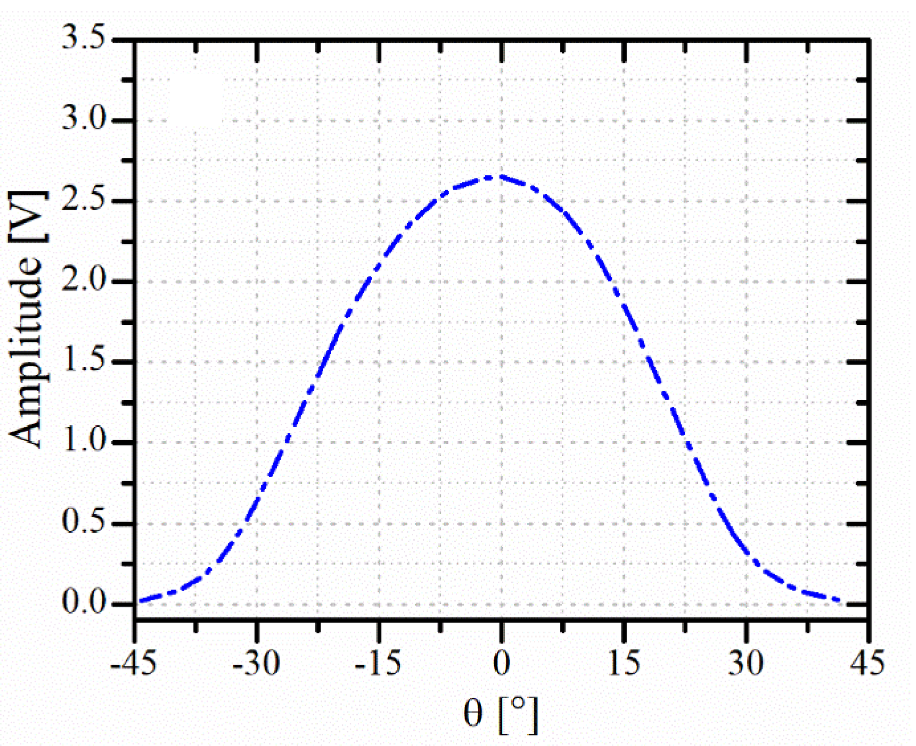

Fig. 5. Output light intensity distribution after passing through a 1 m long POF without sensitive zone

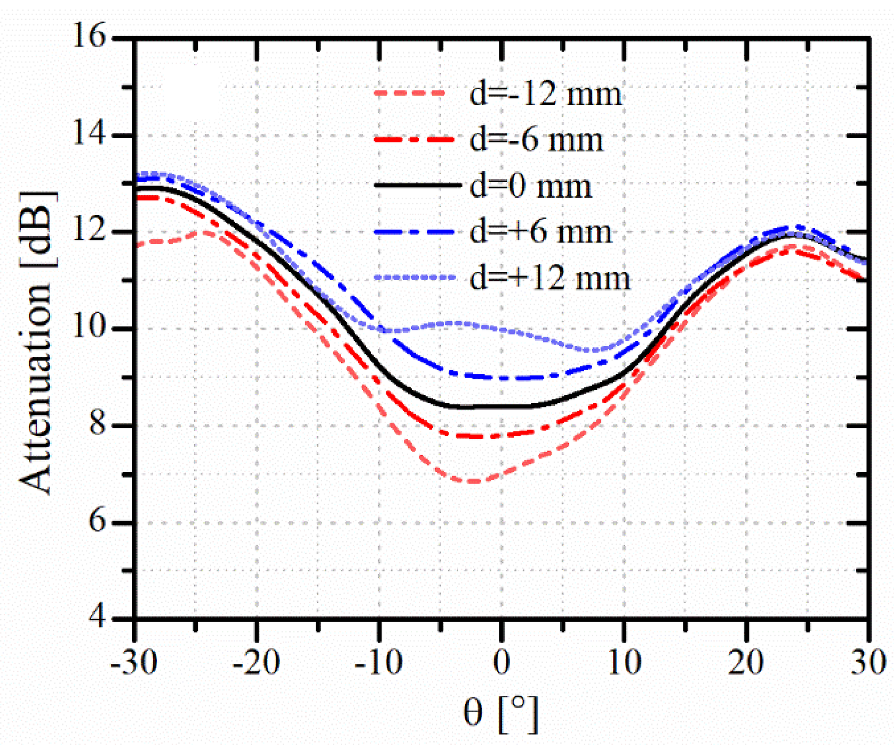

Fig. 6. Attenuation in dB of different modes for beam deflection of -12, -6, 0, 6 and 12 mm

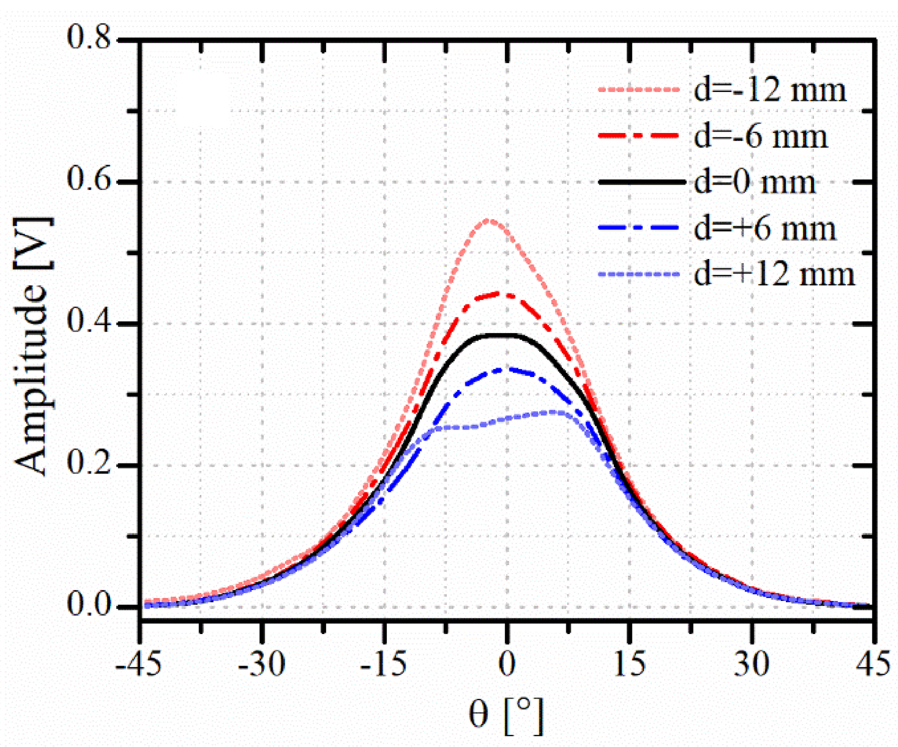

Fig. 7. FOCS output light intensity distributions recorded for beam deflection of -12, -6, 0, 6 and 12 mm

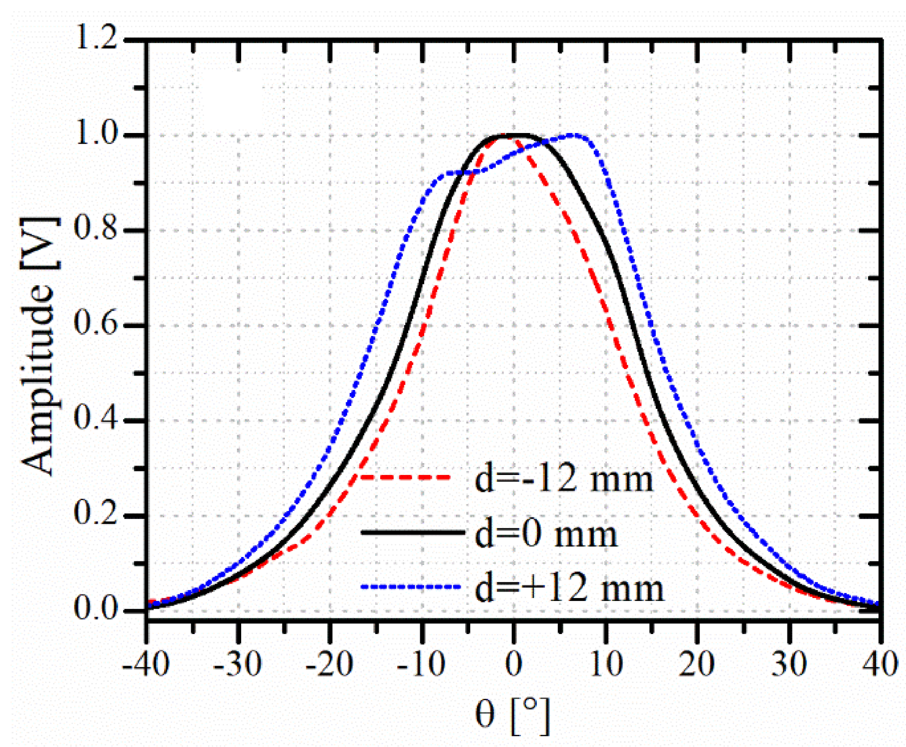

Fig. 8. Normalized output intensity distribution for beam deflection of -12, 0 and 12 mm

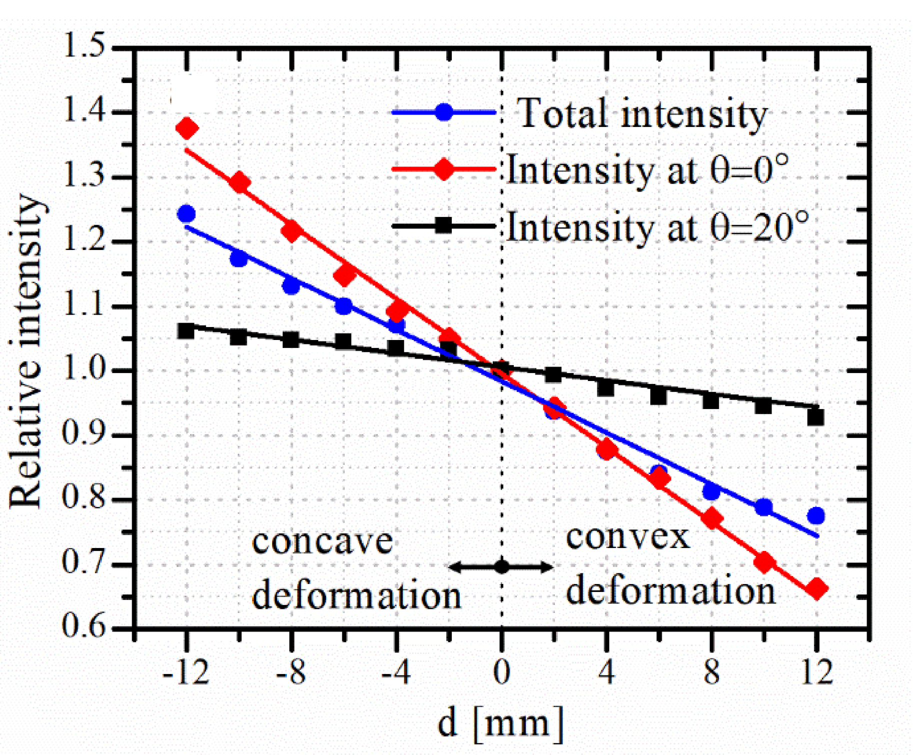

Fig. 9. FOCS relative intensity change with respect to deflection

	Total intensity	Intensity at Θ=0°	Intensity at Θ=20°
Relative Sensitivity [%/mm]	-1.67	-3	-0.42

CONCLUSION: **The mode converter, placed between the LED and the FOCS, excited multiple modes (Fig. 5.), enabling a further examination of bending effects on those modes.**
By observing results given in Fig. 7 it can be noticed that as curvature changes, sensitive zone on the fiber affects the lower order modes (light rays that propagate under small angles with respect to fiber axis) the most. In contrast, higher order modes, highly attenuated at sensitive zone (Fig. 6.), are significantly less affected by changes of curvature. As it can be noticed from Fig. 8. as curvature changes from concave to convex deformation, output intensity distribution is broadened, so there are significant changes in the width of the output intensity distribution with bending deformation (Fig. 10.). This result gives a significant step forward for FOCS based measurement systems by avoiding direct output intensity measurement. Additionally, based on the results given in Fig. 9. it can be concluded that the presence of higher order modes reduces the sensitivity of the FOCS.
In further research dependence of the teeth depth and their spacing on mode dependent attenuation will be examined.

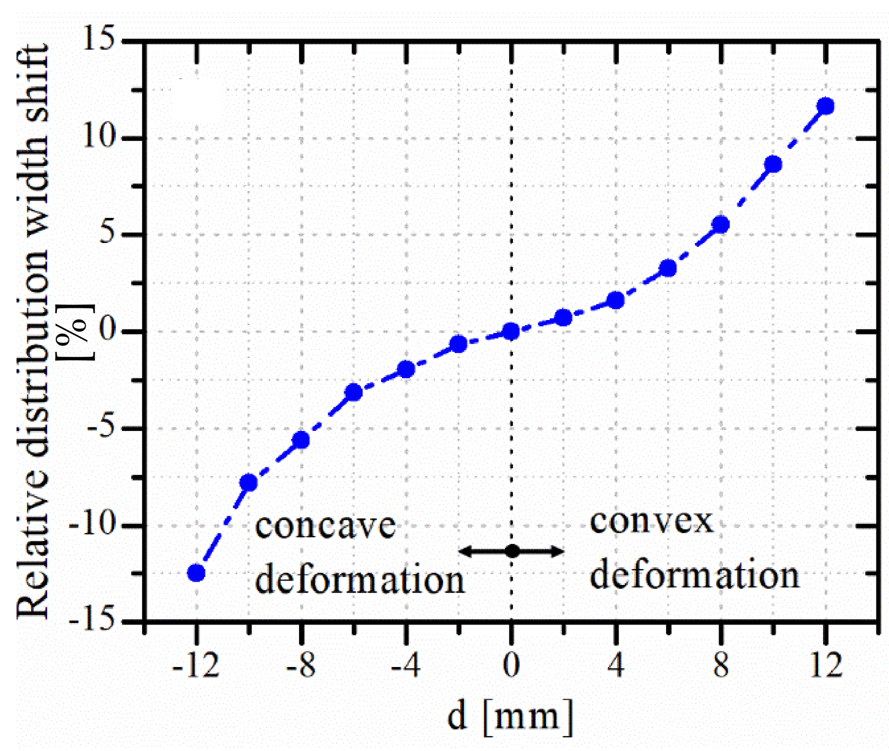

Fig. 10. Relative distribution width shift in dependence of beam deflection