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Abstract

We report on the fabrication of a planar optical sensor system based on channel waveguides with integrated volume Bragg gratings. The photonic structures are written into previously cured inorganic-organic ORMOCER[®] hybrid-polymer substrates by applying the static phase mask technology. The particular combination of the optical component and the chosen substrate lead to a planar sensor structure with ideal characteristics for highly sensitive temperature measurements.

The resulting sensor element shows a linear dependence on temperature changes with a markedly high sensitivity of up to 294 pm K⁻¹, a thirtyfold higher sensitivity as compared to commonly used silica based fiber Bragg gratings.

In respect to the applied interrogation system the achieved sensitivity corresponds to possible acquisition steps of up to 3.4 mK. However, since we define the limit of detection (LOD) by the 3σ criteria, a LOD of up to 20 mK has been found for the fabricated sensor system.

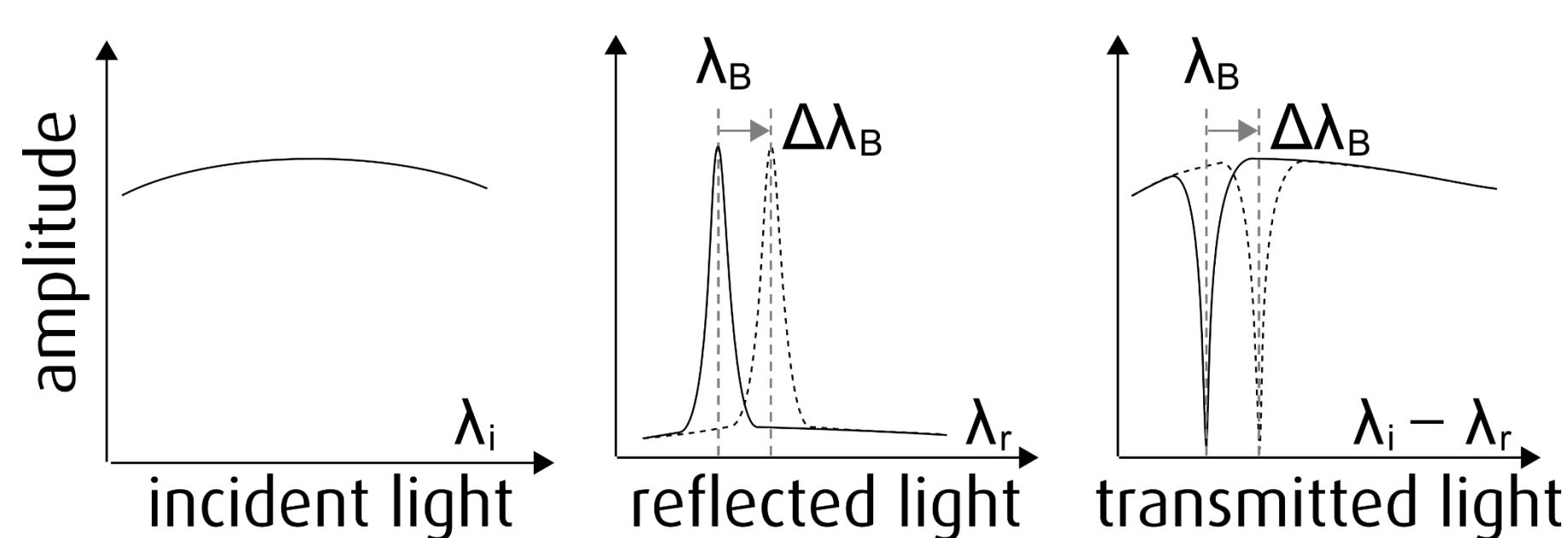
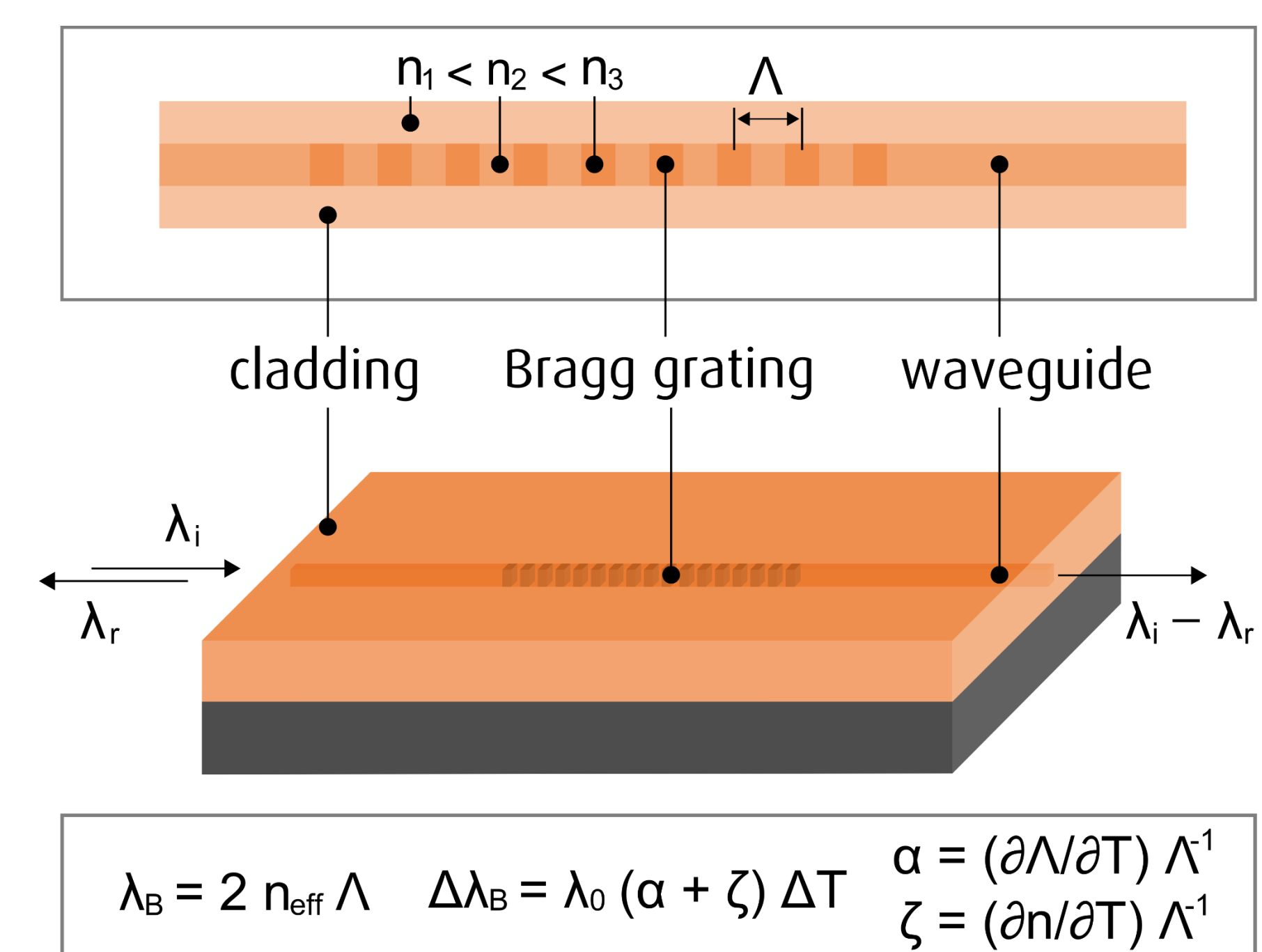
Material

The organically modified ceramics OrmoCore, OrmoClad and OrmoComp[®] (by micro resist technology) were chosen for the fabrication of the sensor.

	OrmoCore	OrmoClad	OrmoComp [®]
$n_{1550\text{nm}}$	1.537	1.521	1.505
$\alpha_{589\text{nm}}$ [K ⁻¹]	-250x10 ⁻⁶	-270x10 ⁻⁶	-290x10 ⁻⁶
ζ [K ⁻¹]	130x10 ⁻⁶	130x10 ⁻⁶	60x10 ⁻⁶

Sensor principle

The sensor is based on an optical planar channel waveguide with an integrated volume Bragg grating (BG), a periodic refractive index modulation within the waveguide with the ability of reflecting a small portion of the incident light spectrum; referred to as the Bragg wavelength λ_B . The applicability of BGs in temperature sensing is favored by the dependence of the BGs effective refractive index n_{eff} and the BGs period Λ on the temperature.



Sensor fabrication and testing

Substrate preparation:

- ORMOCER[®] spin coated onto O₂ plasma treated Si-wafer
- Curing by UV irradiation (F = 2.5 J/cm² at i-line)

Waveguide fabrication:

- KrF excimer laser ($\lambda = 248$ nm, $f = 200$ Hz, $F = 15$ J/cm²)
- Illumination through Cr-amplitude mask in soft contact
- Waveguides of 14 μm height and 12 μm width

Bragg grating fabrication:

- KrF excimer laser ($\lambda = 248$ nm, $f = 100$ Hz, $F = 15$ J/cm²)
- Illumination through phase mask in soft contact
- Grating period $\Lambda_{\text{Clad,Comp}} = 1036$ nm $\Lambda_{\text{Core}} = 1008$ nm

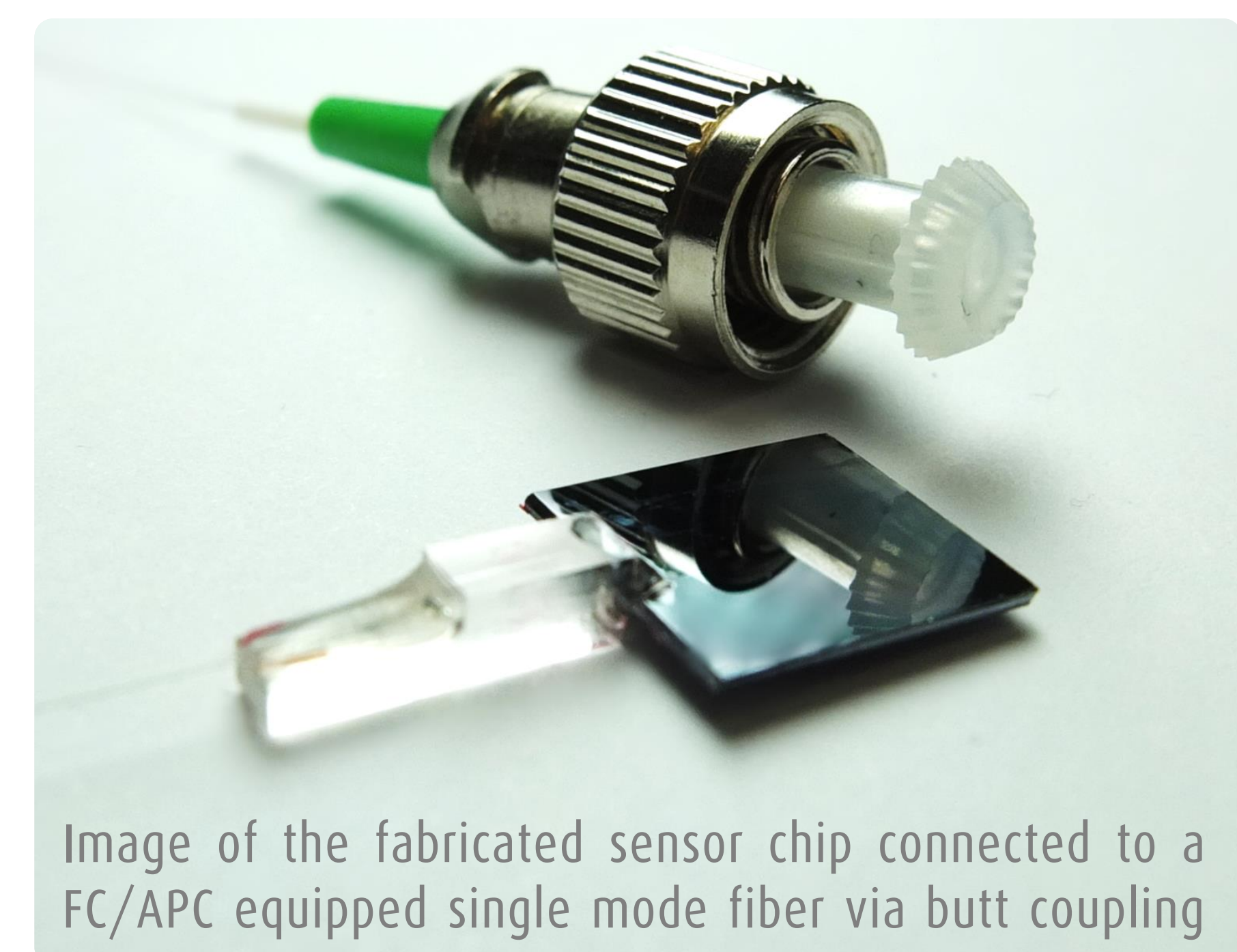
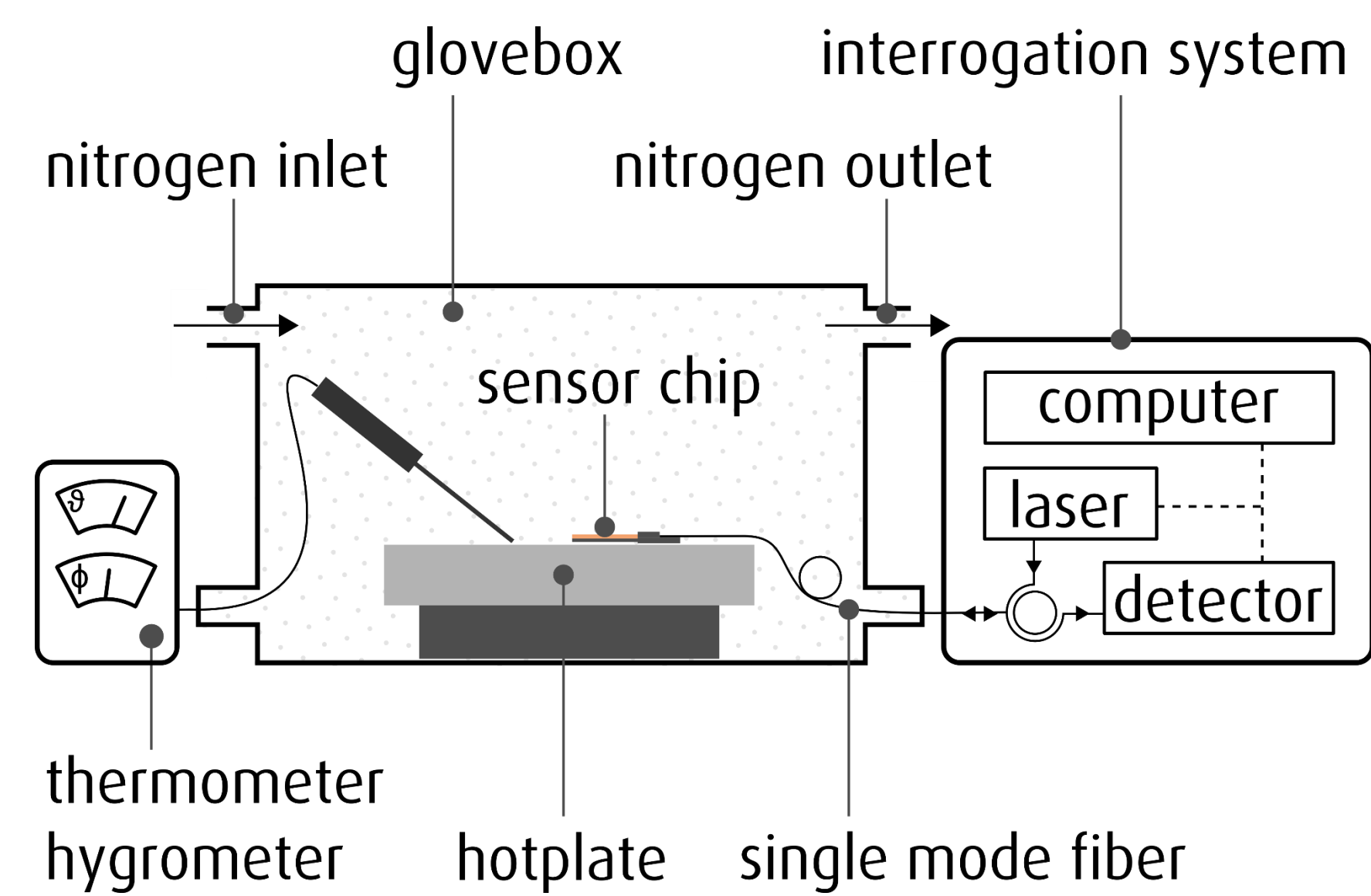
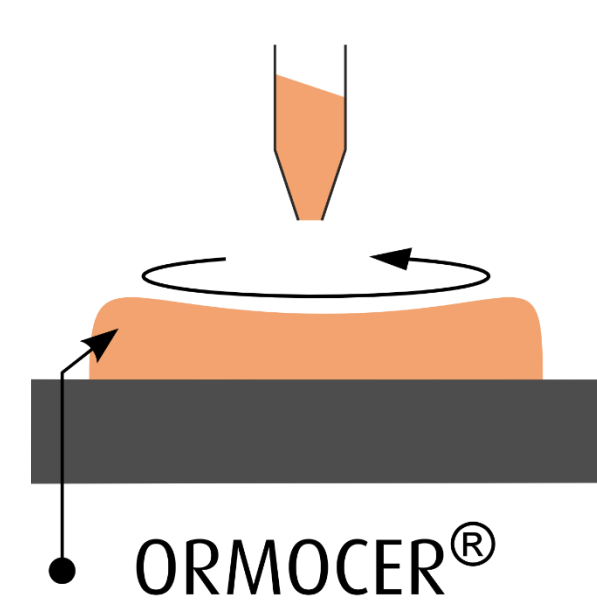
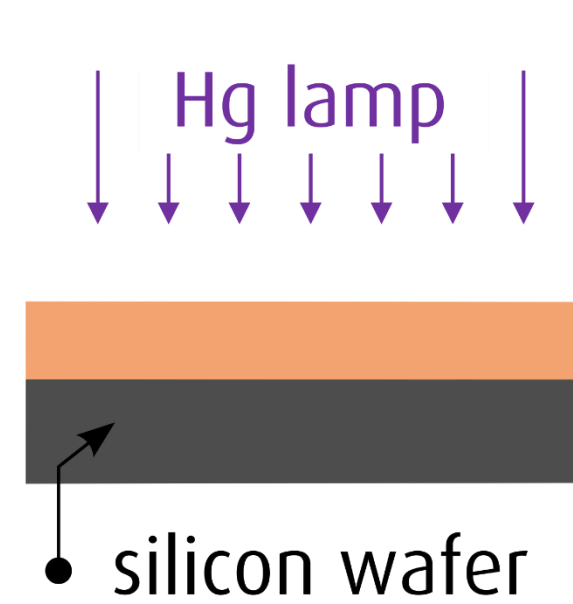


Image of the fabricated sensor chip connected to a FC/APC equipped single mode fiber via butt coupling

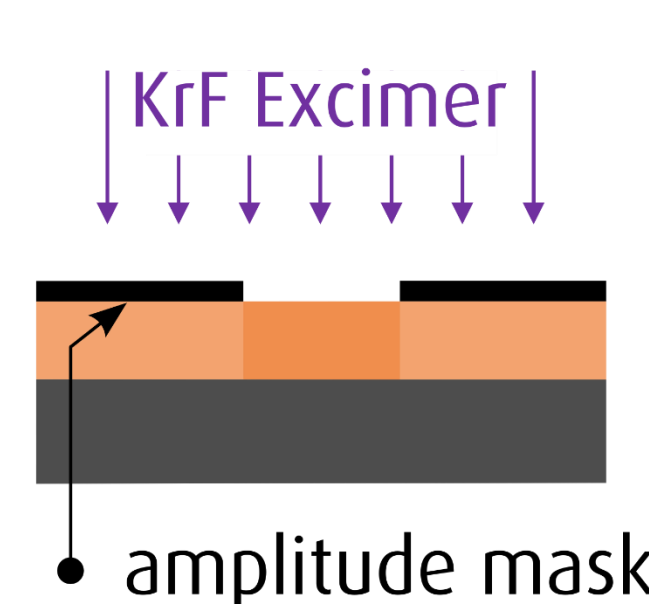
spin on substrate



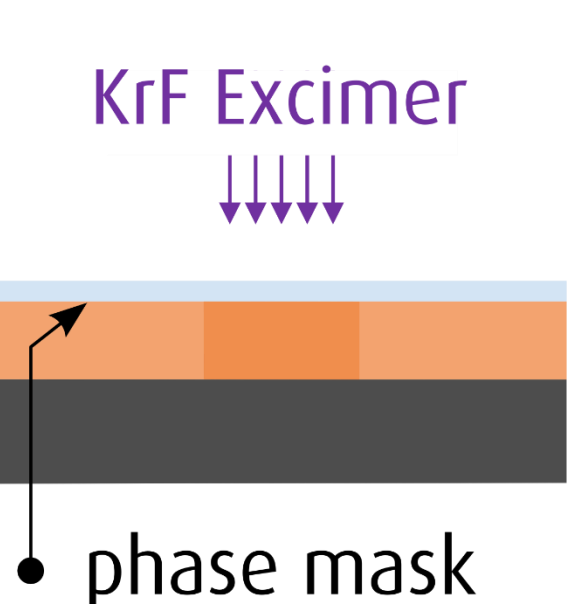
curing



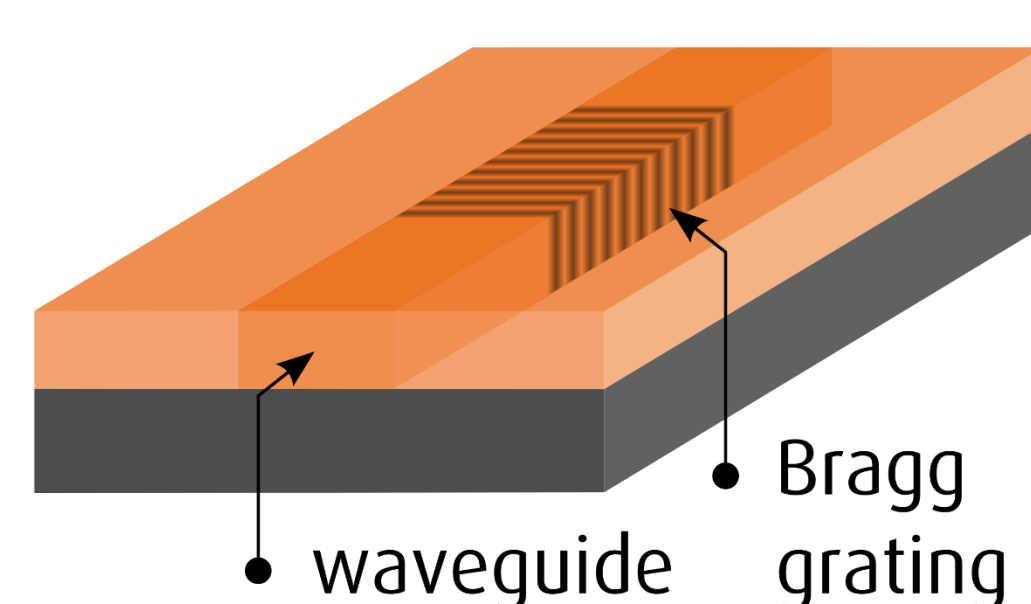
waveguide fabrication



Bragg grating fabrication

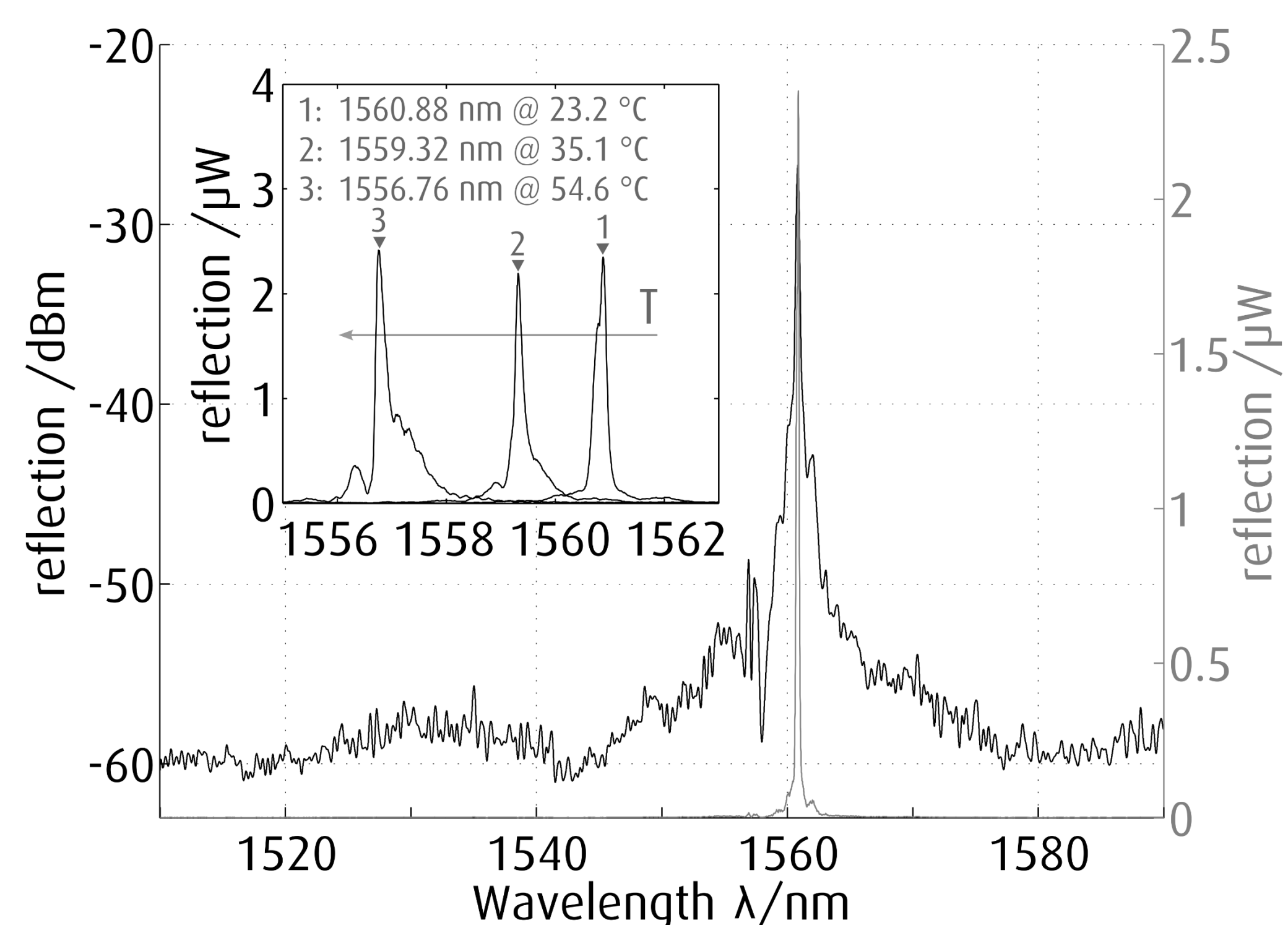


sensor chip

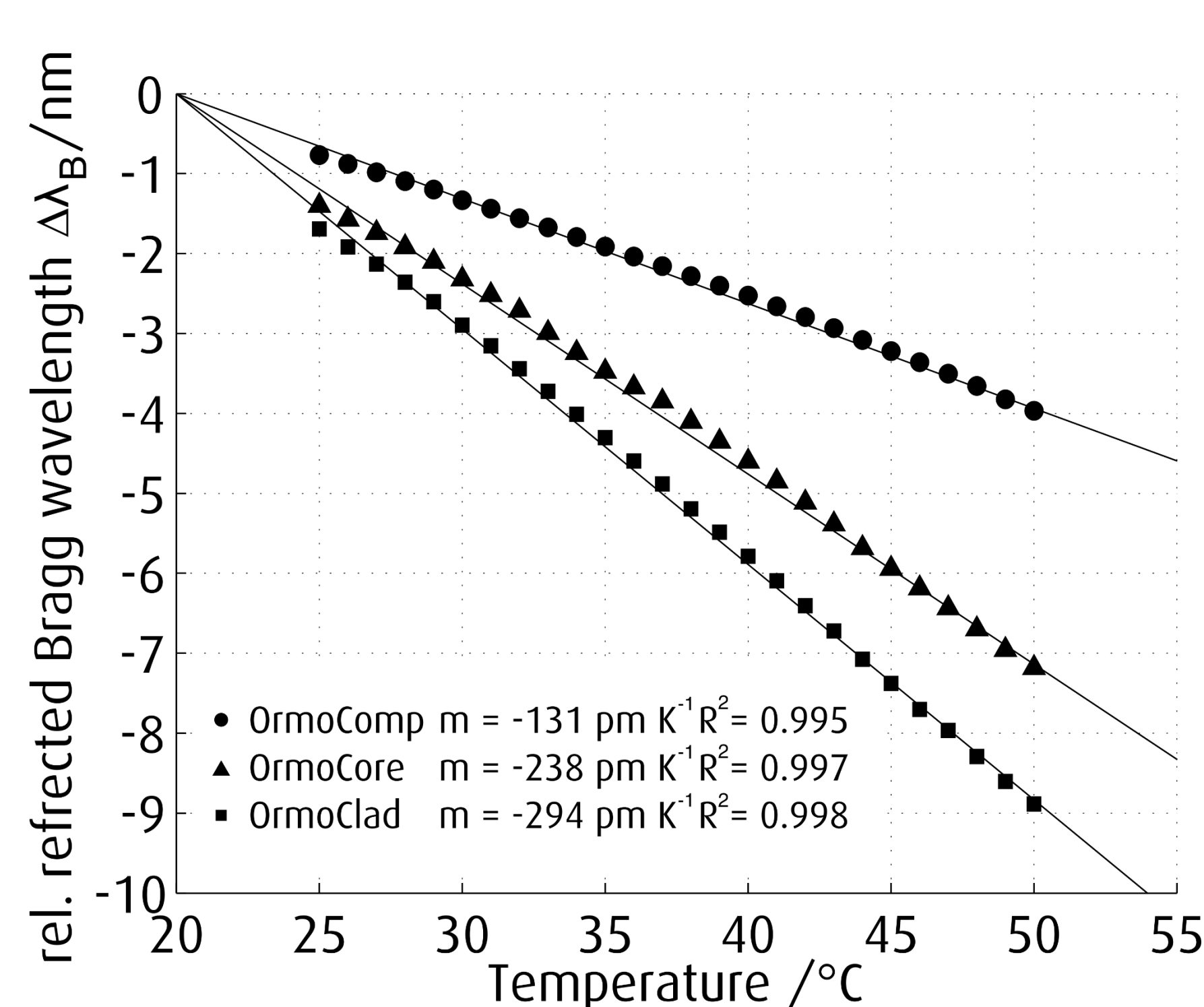


Results

The fabricated ORMOCER[®] channel waveguide Bragg Gratings exhibit well-defined reflections with a small FWHM of down to 130 pm and a reflectivity of up to 78 %. The sensitivities were found to be -131 pm K⁻¹ for the OrmoComp[®],



-238 pm K⁻¹ for the OrmoCore and -294 pm K⁻¹ for the OrmoClad waveguide BG. Thus, a limit of detection of 46 mK for OrmoComp[®], 25 mK for OrmoCore and 20 mK for OrmoClad based BGs is deduced.



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