

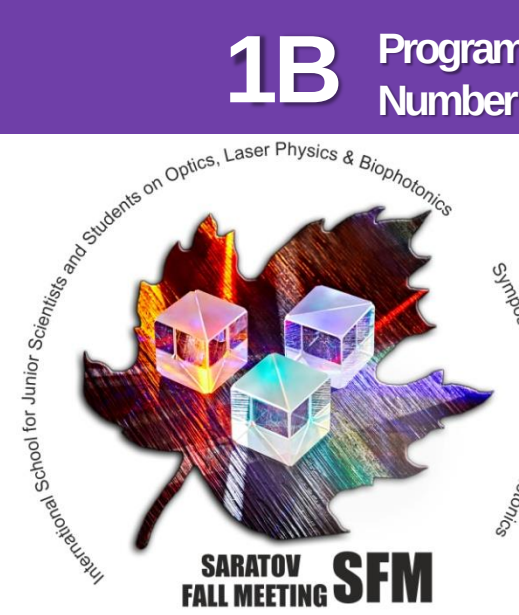
Multi-order diffractive optical element for parallel optical classification of corneal pathologies

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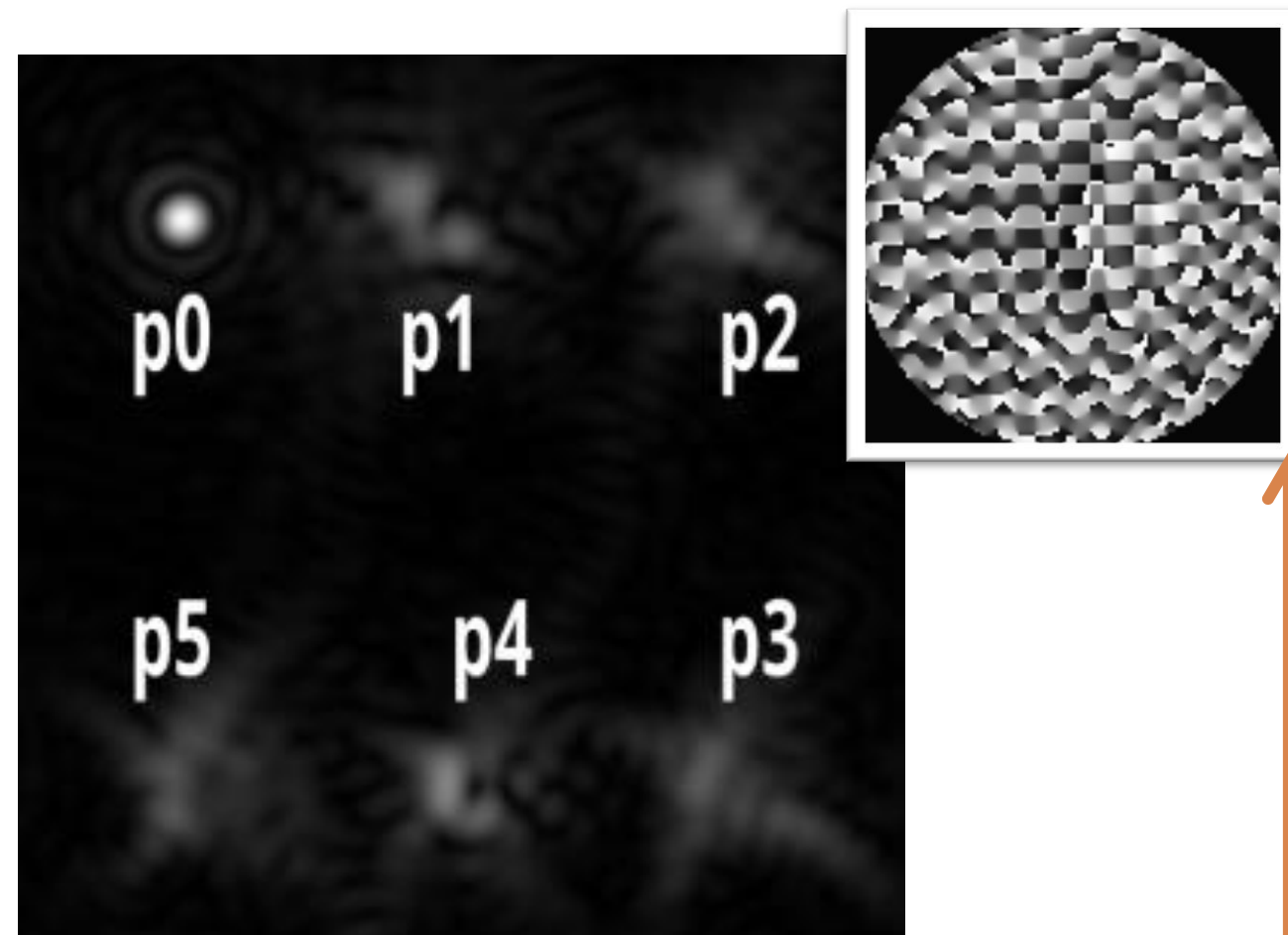
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Introduction

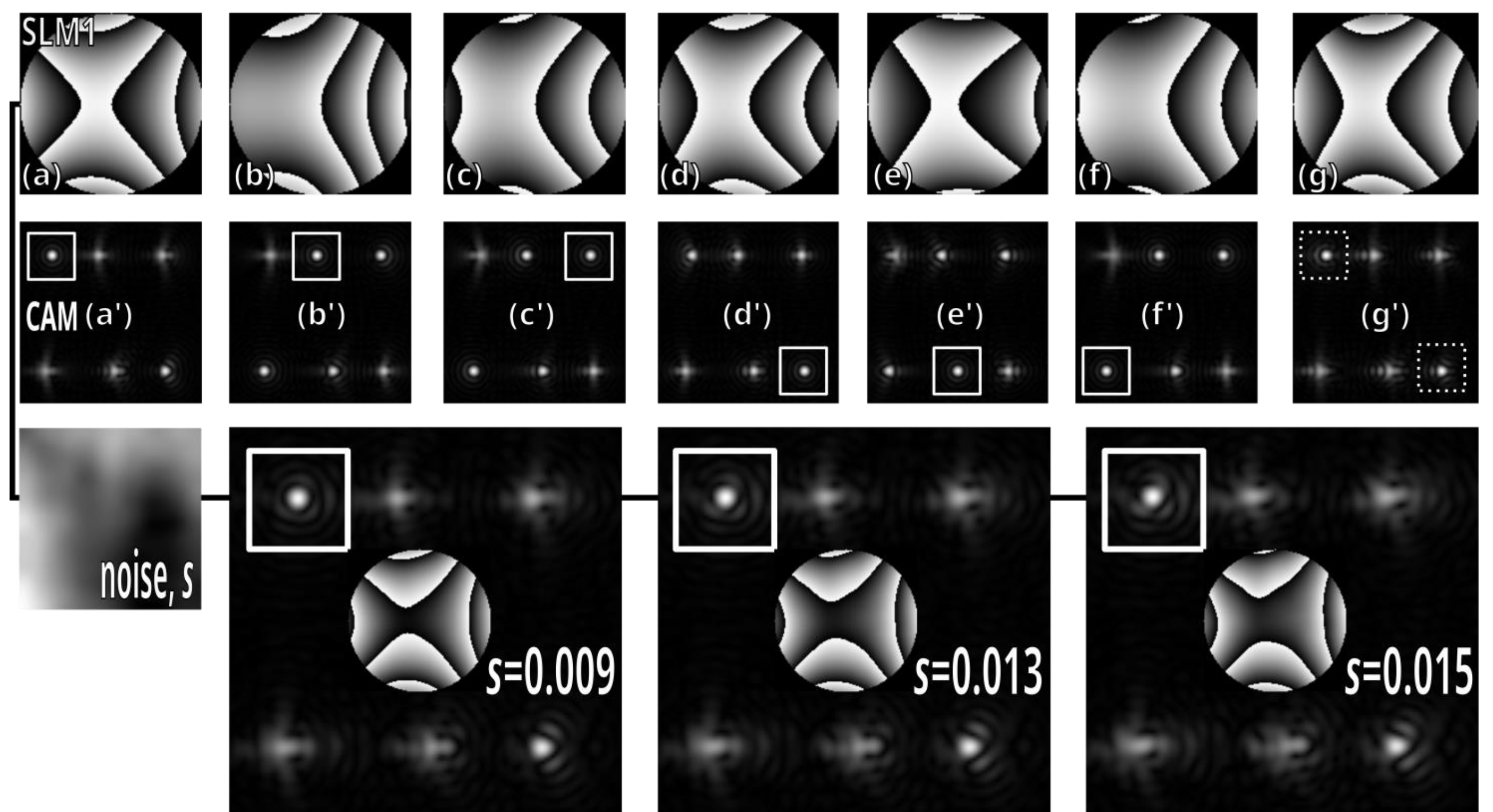
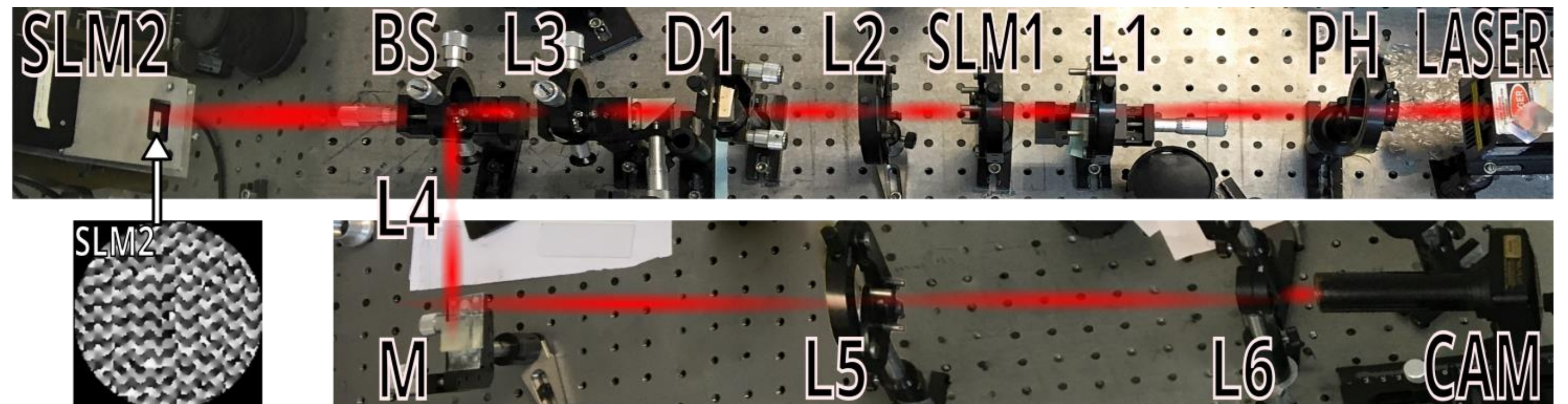
- This study analyzes wavefront aberrations associated with changes in corneal surface curvature. The analysis is based on a dataset of 4,500 Zernike function coefficients describing wavefront aberrations, derived from clinical measurements of healthy individuals and patients with corneal pathologies. The paper presents a concept for a pathology diagnostic system featuring a multi-order diffractive optical element (DOE) that serves as an optical classifier. Sets of polynomials with specific weight coefficients—characteristic of particular types of pathologies—are encoded within each diffraction order of the element.

Results



The figure shows the complex phase of a 6-order DOE (7), which encodes sets of all polynomials up to the 4th order, excluding axisymmetric aberrations, with averaged inverse weights characteristic of the following aberration groups:

- p0 – healthy eye,
- p1 – mild myopia,
- p2 – mild myopia + astigmatism,
- p3 – moderate myopia,
- p4 – moderate myopia + astigmatism,
- p5 – high myopia + astigmatism. V



The figure shows intensity distributions in the focal plane of the DOE (8) when illuminated by a wavefront whose phase is defined by a superposition of polynomials—excluding axially symmetric aberrations—with weights corresponding to a healthy eye and to various pathologies.

$$\tau(x, y) = \sum_l \left(\sum_{p,q} \exp \left[i 2 \pi d_{lpq} Z_{pq}(x, y) \right]^* \right) \exp \left[i (a_l x + b_l y) \right]$$

where d_{lpq} are the weighting coefficients of the Zernike polynomials encoded in the DOE, and a_l and b_l are the carrier frequencies along the x - and y -axes, respectively, for the diffraction orders.

Discussion

We capture the intensity distribution using a camera and detect the formation of a correlation peak—or a similar pattern characteristic of the full or partial compensation of aberrations associated with a specific pathology—to automate the diagnostic process.

Conclusion

Key Finding 1

This paper presents a concept for an optical classifier of corneal pathologies that accounts for high-order aberrations.

Key Finding 2

Grouping by nine diffraction orders ensures the classification's robustness against variations in corneal shape. Numerical simulation results confirm the formation of correlation peaks in the target diffraction orders upon complete phase inversion of the corresponding aberrations.

Key Finding 3

The use of the proposed method significantly enhances the reliability of automated diagnostics. The proposed technology paves the way for the development of portable, instant screening systems that operate without the direct involvement of a physician.