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Free-space light coupling using curved micromirrors

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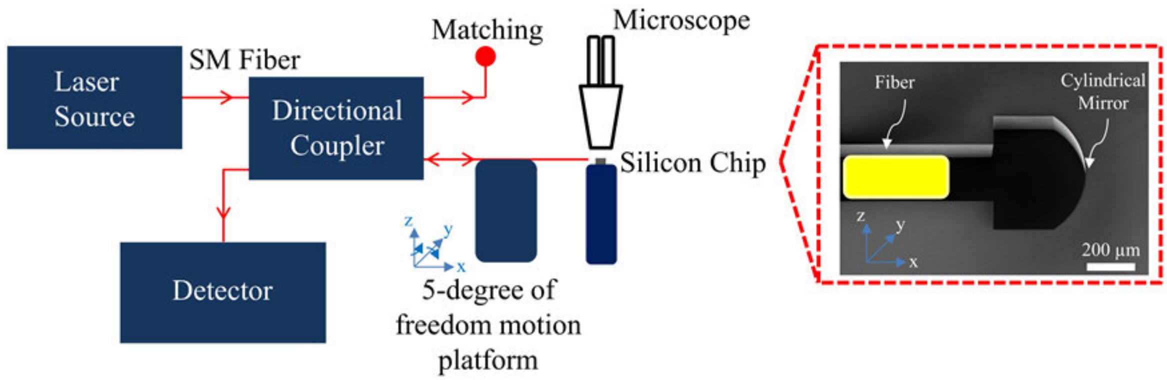


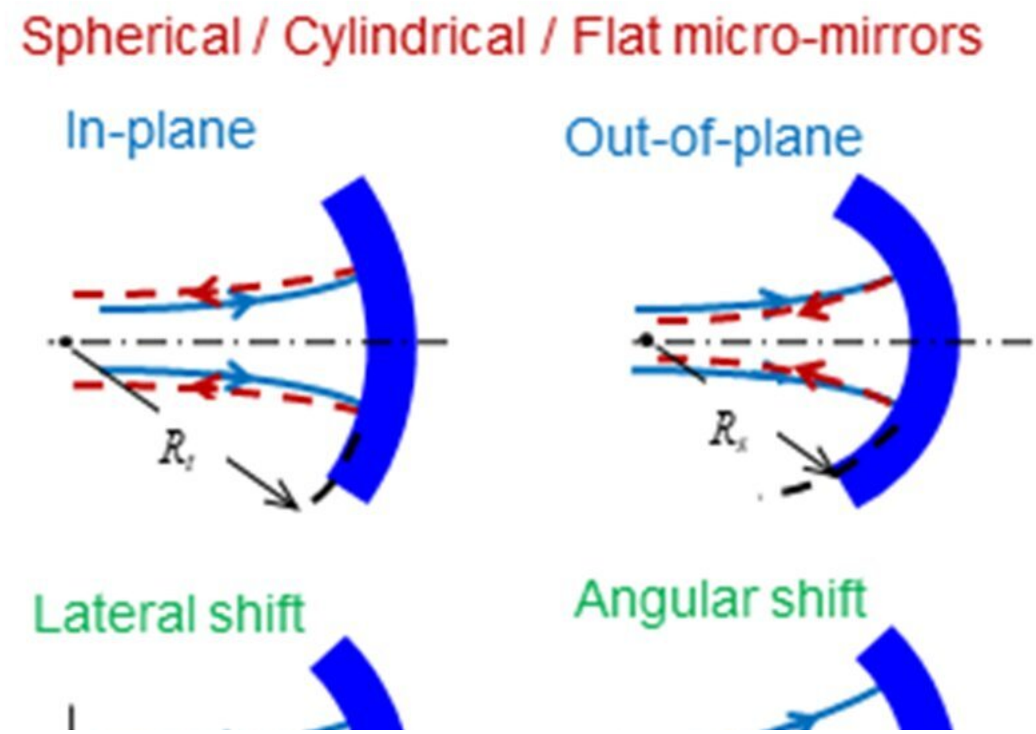
Silicon micromirrors coupling efficiency measurements using single-mode optical fibers fed from monochromatic light source, a directional coupler and an optical detector. Credit: Yasser M. Sabry et al, *Journal of Optical Microsystems* (2022). DOI 10.1117/1.JOM.2.3.034001

Micromirrors are micrometer-scale mirrors that are widely used in many applications, mainly in optical-fiber telecommunications, optical scanners, and optical instrumentation. Micromirrors can be integrated within photonic chips, which can be seen as the miniaturized counterparts of the macroscopic optical benches. In optical communication, micromirrors are important building blocks for cross couplers, variable optical attenuators, and external cavity tunable lasers.

In all those applications, the efficiency of coupling light in and out from these micromirrors is a key performance indicator governing the signal quality. In instrumentation, micromirrors are also important building blocks of optical interferometers and optical resonators. In these cases, the coupling efficiency is also a key performance indicator affecting the metrological properties.

In a research paper recently published in the *Journal of Optical Microsystems*, researchers led by Yasser Sabry of Ain Shams University in Egypt analyzed micromirror behavior depending on different characteristics, such as shape, height, and surface quality. They also analyzed the impact of misalignment of incident light, considering both off-axis misalignment and angular misalignment.

The vast majority of micromirrors are flat, and the corresponding height is usually limited to 80 μm due to microfabrication constraints. Beyond this limit, the verticality and roughness of the etched surface deteriorates. One has to maintain the light spot size smaller than the mirror height to achieve reasonable throughput. Deeper micromirrors are highly desirable, but they are difficult to fabricate. Curved micromirrors are in principle more interesting than flat mirrors, although they are more difficult to fabricate. Many recently reported techniques have demonstrated manufacturing of such micromirrors with both 2D and 3D shapes. The researchers therefore proposed a detailed analysis of the potential of such curved mirrors.



Schematic illustration for the coupling cases under study. Credit: Yasser M. Sabry et al, *Journal of Optical Microsystems* (2022). 10.1117/1.JOM.2.3.034001.

They studied in detail the free-space coupling of Gaussian light beams using flat and curved micromirrors. The theoretical background and the non-ideal effects, such as limited micromirror extent, asymmetry in the curvature of spherical micromirrors, misaligned axes and micromirror surface irregularities were analyzed. The derived formulas were used to study and compare theoretically and experimentally the behavior of flat (1D), cylindrical (2D), and spherical (3D) micromirrors. The analysis focused on the regime of dimensions in which the curved micromirror radius of curvature is comparable to the incident beam Rayleigh range, also corresponding to a reference spot size.

The researchers derived a transfer matrix-based field and power coupling coefficients for general micro-optical systems, accounting for different matrix parameters in the tangential and sagittal planes of the microsystem, taking into account the possible non-idealities. They presented the results in terms of normalized quantities such that the findings remain general and applicable to different situations. Additionally, silicon micromirrors were fabricated with controlled shapes and were used to experimentally validate the coupling efficiency in visible and near infrared wavelengths.

More information: Yasser M. Sabry et al, Critical analysis of in-plane free-space light beam coupling using photonic curved micromirrors, *Journal of Optical Microsystems* (2022). DOI: 10.1117/1.JOM.2.3.034001

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