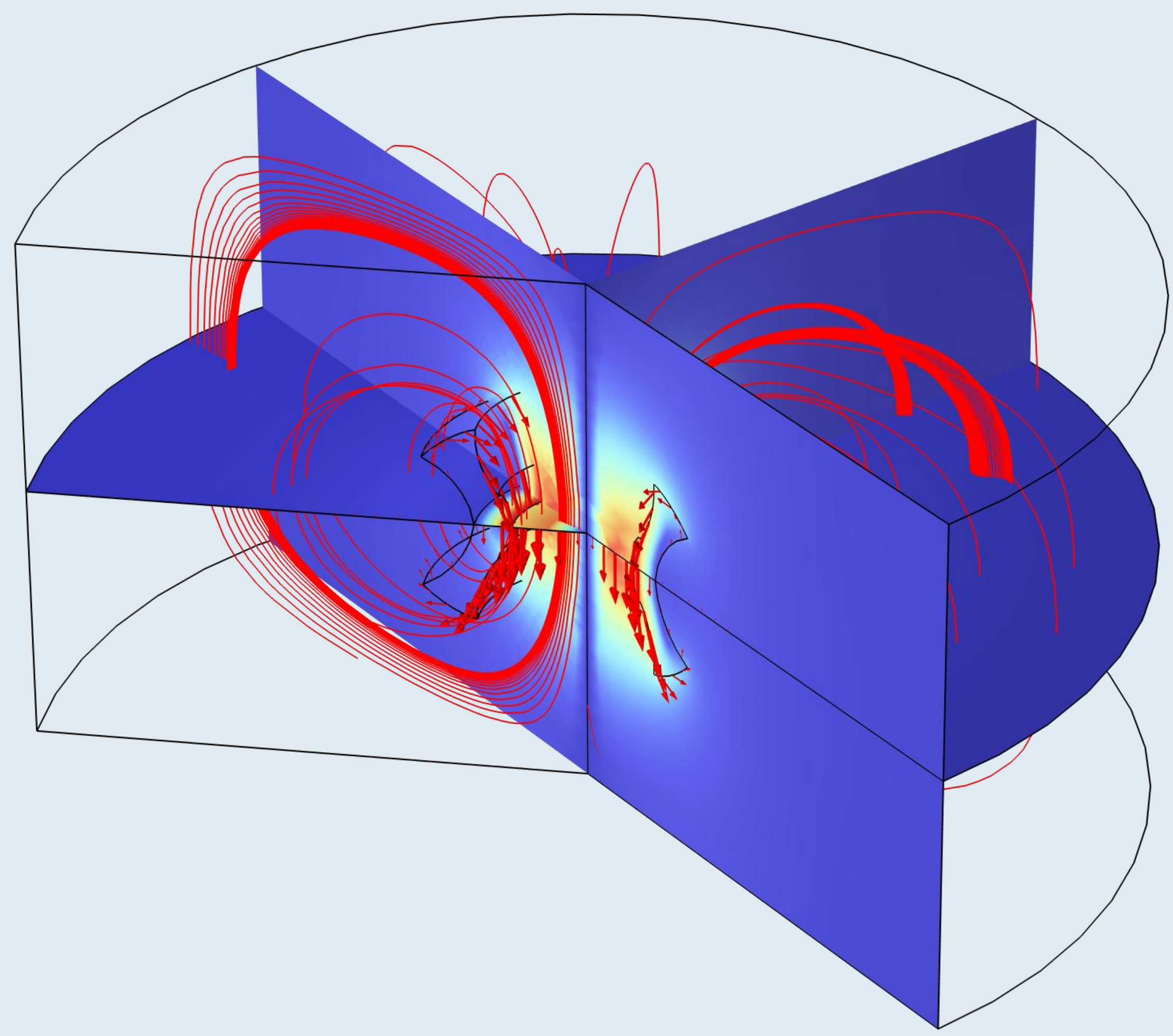




Shape Optimisation of STO Dielectric Resonator

Shape optimisation of a strontium titanate (STO) resonator for a Pentacene doped p-terphenyl maser (microwave amplification by stimulated emission of radiation) for enhanced magnetic field confinement.

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Abstract

Pentacene-doped p-terphenyl masers require strong microwave magnetic field coupling between the resonant cavity mode and the spin active gain medium. This work uses COMSOL Multiphysics® 6.3 to optimise the cross-sectional shape of an STO dielectric resonator operating near the 1.45 GHz maser transition.

The optimisation increased the magnetic filling factor from 0.53 to 0.77, with different initial geometries converging towards a similar non-circular resonator shape, indicating a robust optimisation trend and a better magnetic field confinement.

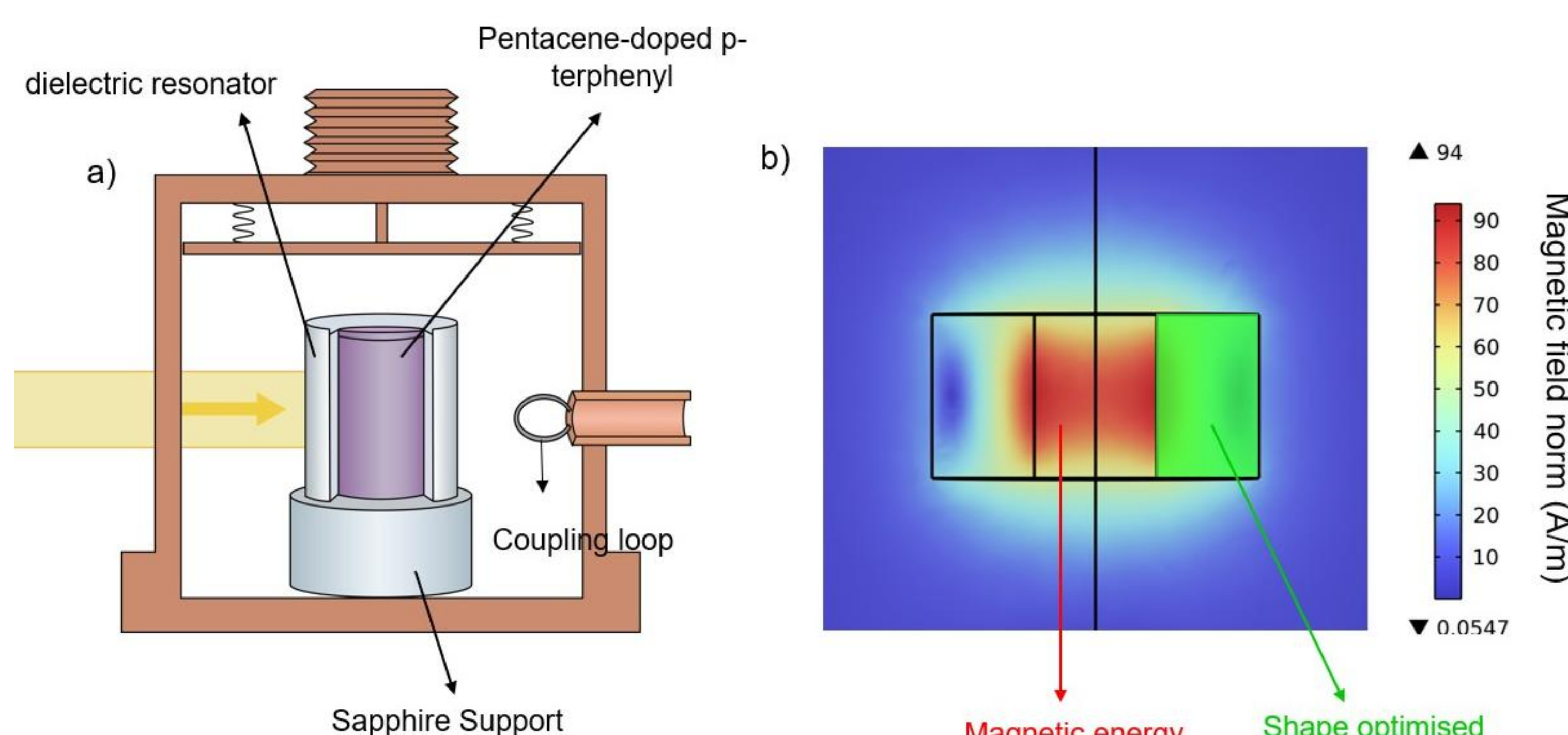


Figure 1. a) Maser cavity schematic and simulated magnetic-field localisation in the gain region. b) The dielectric resonator defines the shape-optimised region.

Results

The magnetic filling factor increased from 0.53 to 0.77 after shape optimisation, corresponding to a 45% relative increase in the fraction of microwave magnetic energy concentrated in the gain region.

Different initial polygonal cross-sections, including quadrilateral, hexagonal, octagonal and decagonal geometries were tested. Despite the different starting shapes, the optimisation produced a similar curved, non-circular boundary trend. The agreement between these independent starting geometries indicates a robust optimised shape trend, rather than a mathematically proven global optimum.

Methodology

A 2D axisymmetric RF eigenfrequency model was simulated around 1.45 GHz. The dielectric boundary was optimised using Deformed Geometry and Free Shape Domain, starting from four different polygonal geometries.

The objective was to maximise the magnetic filling factor, defined as the fraction of microwave magnetic energy confined within the gain region:

$$\eta_H = \frac{\int_{V_{gain}} \mu_0 |\mathbf{H}|^2 dV}{\int_{V_{total}} \mu_0 |\mathbf{H}|^2 dV}.$$

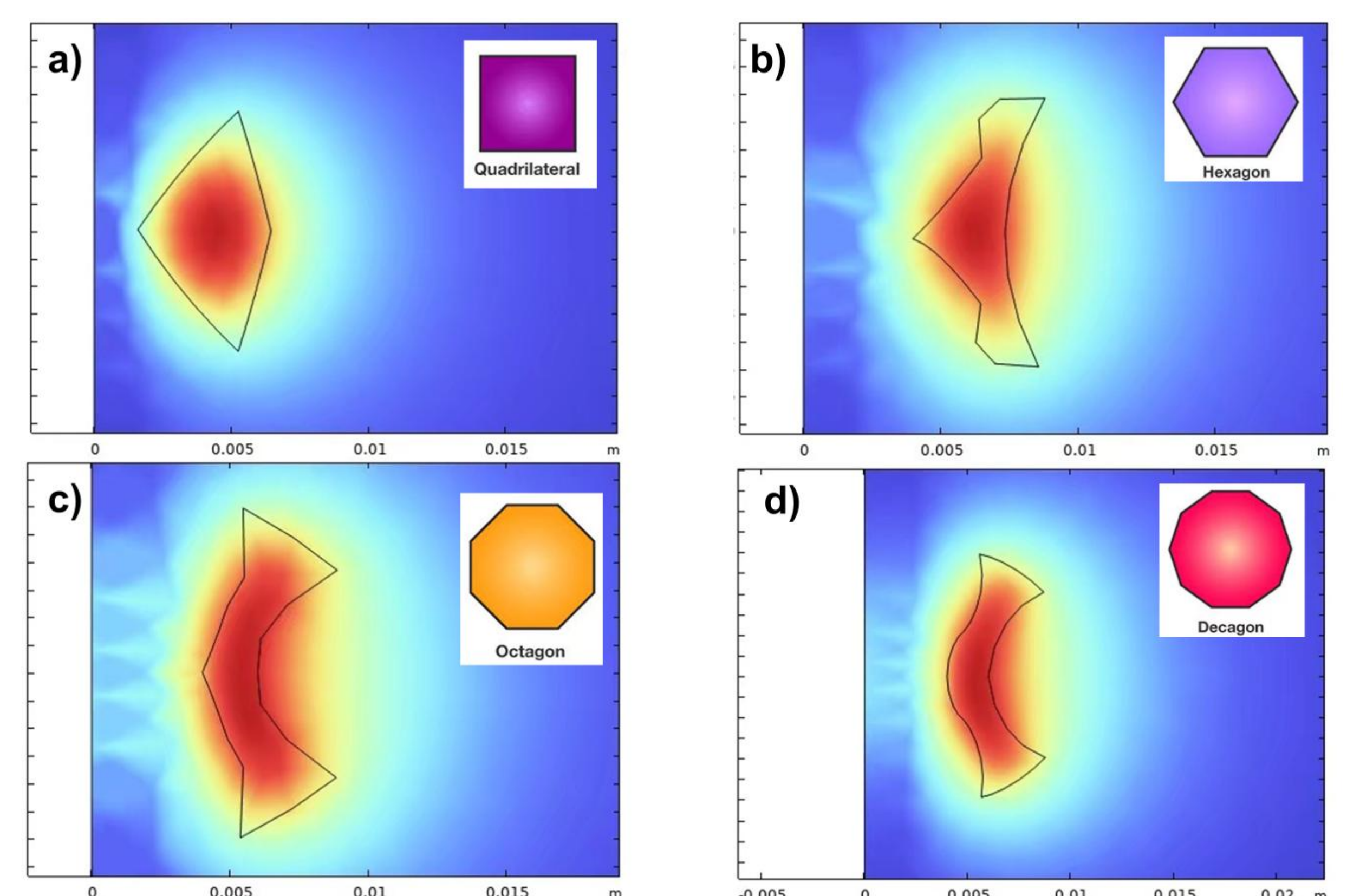


Figure 2. Shape optimisation from different initial polygonal cross-sections. Black outlines show the final optimised dielectric boundaries.

REFERENCES

- [1] M. Oxborrow, J. D. Breeze, N. M. Alford, "Room-Temperature Solid-State Maser", *Nature*, 488 (vol.), 353–356 (pp.), 2012.
- [2] A. E. Siegman, *Microwave Solid-State Masers*, McGraw-Hill, New York, 1964.
- [3] E. M. Purcell, "Proceedings of the American Physical Society", *Physical Review*, 69 (vol.), 681 (pp.), 1946.
- [4] J.-M. Le Floch, N. Delhote, M. Aubourg, V. Madrangeas, D. Cros, S. Castelletto, M. E. Tobar, "Rigorous Analysis of Highly Tunable Cylindrical Transverse Magnetic Mode Re-Entrant Cavities", *Journal of Applied Physics*, 119 (vol.), 153901 (pp.), 2016.

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