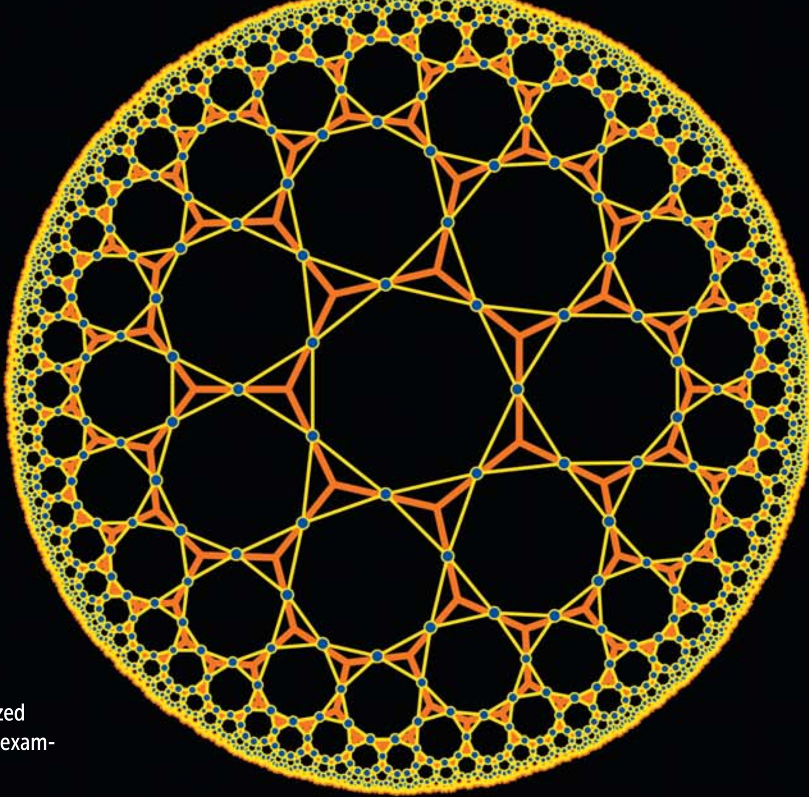
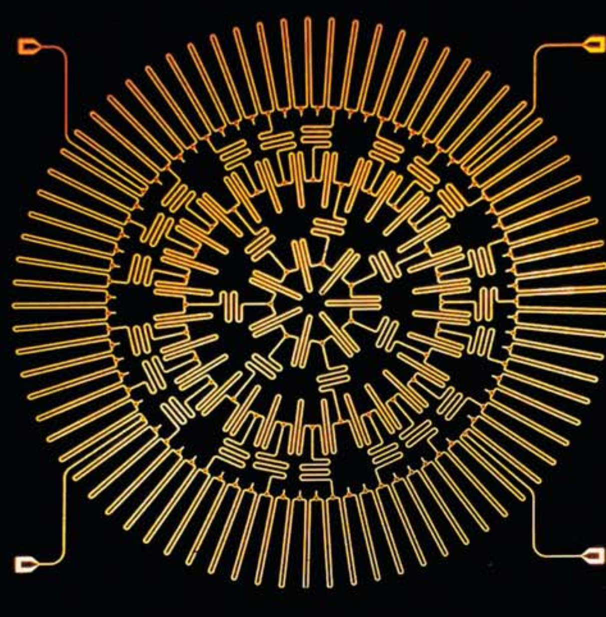
Non-Euclidean geometry on a chip



Equal-sized squares or hexagons can be arranged to fully tile a flat, two-dimensional plane, which has zero curvature. Pentagons can't tile a plane, but they can be wrapped into a 3D dodecahedron and cover a sphere. Heptagons can't be tiled at all, at least in familiar Euclidean geometry. A regular tiling of heptagons would require a hyperbolic surface with negative curvature—every point is a saddle point where space curves away from itself. Unlike a sphere, which has positive curvature, a hyperbolic surface cannot be realized in Euclidean space without distorting it. The top panel shows an example: a 2D projection (orange) of a regular heptagonal tiling.



Alicia Kollár (now at the University of Maryland) and colleagues at Princeton University have demonstrated a novel way of fabricating an effective hyperbolic space using a 2D network of superconducting circuits. Each circuit is a coplanar waveguide resonator, a platform for so-called cavity quantum electrodynamics (see PHYSICS TODAY, November 2004, page 25). As is the case for coaxial cables, bending the resonators doesn't change their behavior, which is determined only by the length of the meander. The arrangement of 140 resonators, each 7.5 mm long, in the bottom photo corresponds to the 29 innermost orange tiles of the top image. Photons hop from resonator to resonator along paths that correspond to the yellow lines in the top image. Together, the paths define what the researchers call a heptagon-kagome lattice. The result is an artificial photonic material in an effective hyperbolic curved space. Many standard approaches of solid-state physics break down in non-Euclidean space; the researchers had to resort to numerical simulations to find their material's band structure: a rare combination of a flat band and an energy gap. Adjusting the resonator layout and couplings will allow exploration of a large variety of other lattices and curved spaces. (A. J. Kollár, M. Fitzpatrick, A. A. Houck, *Nature* **571**, 45, 2019.) —RJF