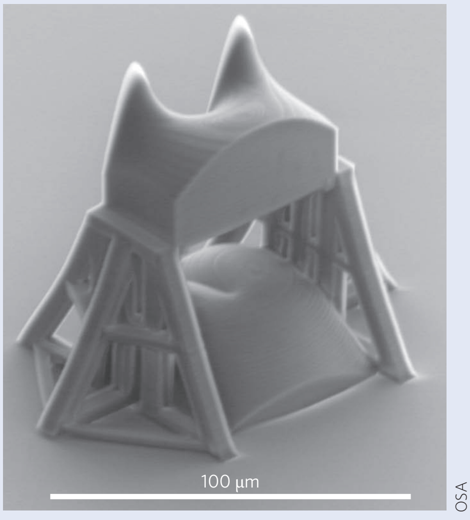
INTEGRATED OPTICS

Vortex sorter

Optical vortex beams can be used for particle manipulation, quantum optics, communications and other applications. In communications, throughput can be increased by spatially overlapping modes with different orbital angular momentum. The modes can be separated, or demultiplexed, by various bulky approaches including by pairs of spatial light modulators, or centimetre-scale diffractive elements made by a computer numerical control (CNC) router or related milling approaches. However, such components are relatively large for integrated applications, for example, for use on fibre tips.

Now, Shlomi Lightman and colleagues in Israel, have employed direct laser printing to make micrometre-scale structures for multiplexing and demultiplexing orbital angular momentum states of light (*Optica* **4,** 605–610; 2017). A first demonstration uses two diffractive phase elements, whereas a second demonstration shows an integrated device (pictured) combining the required elements.

The team used a commercial 3D direct laser writing system to print structures from a material with a refractive index of about 1.51 at 780-nm wavelength.



OSA

After printing, the structures were rinsed in developer and treated with isopropanol for clean-up. The volumes of the two components (transformer and corrector) are 60 × 60 × 32 μm^3 and 60 × 30 × 51.5 μm^3, respectively; the two components were separated by a distance of 60 μm.

Vortex beams were created using a phase-only reflective spatial light modulator illuminated by a Ti:sapphire laser in continuous-wave mode; beams with orbital angular momentum from $-3\hbar$ to $3\hbar$ were generated. In the demonstration, beams were spatially separated 9.4 μm per angular momentum unit. In the system, the topological charge must be less than 5, but this can be increased by adjusting the dimensions between the two elements; the authors claim that vortex beams with a charge of 10 can be processed. The team adjusted the printing process to analyse the effect of surface roughness, which affects the performance of the devices. As expected, smoother surfaces result in less side-lobes and crosstalk.

The experiments were repeated for the wavelengths 690, 790, 890 and 990 nm and demonstrated a 300-nm bandwidth, with the main limitation being dispersion of the photoresist. The team believes that design optimization can enable operation over the wavelength range ~300–2,000 nm. However, beyond this range the polymer will become opaque and other materials should be employed.

DAVID PILE

SILICON PHOTONICS

Modulators make efficiency leap

Significant improvements in the loss and drive voltage of silicon photonics-based optical phase modulators look set to benefit both short-reach and long-distance data communications.

Jeremy Witzens

Optical modulators are vital components in optical communications systems providing control over the phase or amplitude of a light signal, allowing it to be encoded with information to be transmitted. As communications systems evolve there is a desire for such modulators to become increasingly energy efficient at their task, operate at higher speeds and ideally be fabricated on silicon to aid the integration of electronics and optoelectronics. In this issue of *Nature Photonics*, two research groups in Japan independently report[1,2] much improved silicon photonics electro-optic modulators that exploit hybrid integration of a III–V compound semiconductor (InGaAsP) on top of a silicon waveguide (Fig. 1).

Modulators come in two main types: (1) electro-absorption modulators, which typically only function over a restricted wavelength range close to the absorption edge of the material and provide amplitude modulation but not independent phase modulation; and (2) modulators relying on embedded phase shifters. The latter are commonly configured in a two-arm Mach–Zehnder interferometer (MZI) design and can operate over a wide optical bandwidth. This functionality is used in nested IQ-modulators where both in-phase (I) and quadrature (Q) (90° phase offset) carrier signals are manipulated and combined to produce a complex-valued modulated signal with independent control of both amplitude and phase.

In the papers of Jae-Hoon Han *et al.*[1] and Tatsurou Hiraki *et al.*[2], MZI phase modulators with a 3–5 times improvement