PHASE CONTROL

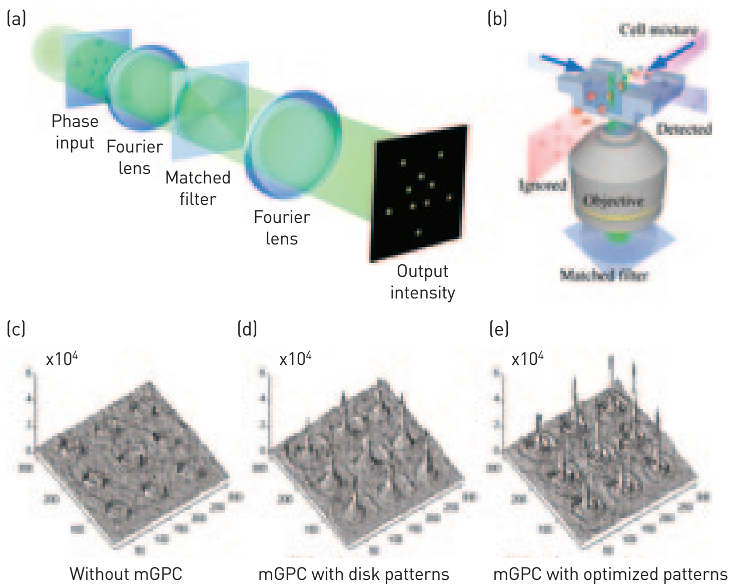
Robust and Low-Cost **Light Shaping**

Phase-only spatial light modulation is used to shape light in microscopy, micromanipulation, microfabrication and biophotonics. One application of phase modulation is the creation of dynamic optical traps for directly controlling the motion of microscopic particles by using programmable spatial light modulators (SLMs).[1,2] Similarly, light can be phase-sculpted to match and target biological material or trigger localized biochemical reactions.[3] Despite its versatility, phase-only spatial light modulation requires pricey SLMs, which limit its use in photonics research. However, consumer projectors are much more affordable. Researchers have started to explore using projectors based on liquid-crystal-on-silicon (LCoS) as binary-only phase modulators by replacing the incoherent light source with a laser of appropriate polarization.

Using two modified pocket pico-projectors, we have demonstrated beam shaping based on matched filtering generalized phase contrast (mGPC).[4] One projector is encoded with dynamic correlation target phase patterns that are directly mapped into intensity spikes. The other projector acts as a tunable matched filter combining GPC and phase-only correlation.

Although these modified projectors can be operated as binary holograms, mGPC offers advantages similar to GPC. Because mGPC is based on a 4*f* geometry, it does not have a strong undiffracted zero-order light that would disturb the sample plane or waste optical energy. The fast encoding into the LCoS by copying and translating a basis correlation target pattern enables real-time reconfigurability of multiple intensity spots without the need of high-end resources. Such simplicity also prevents the formation of ghost orders, speckles and spurious phase variations. Therefore, mGPC-generated light propagates in a well-defined manner and is useful for axially extended applications like active optical sorting or counter-propagating traps.[2,5] Since mGPC borrows features of phase-only optical correlation, the generated output spikes are significantly stronger than the background noise caused by surface imperfections in consumer LCoS devices.

Because many research applications require a specific fixed beam size (e.g., manipulation of microscopic tools or cells, programmable microscopy or microfabrication), a fixed fabricated matched filter can be used to increase overall light efficiency. Replacing the second projector would also make the beam-shaping system more compact. The correlation pattern and filter can be optimized to increase the space bandwidth, thus producing narrower, more intense output spikes.[4] OPN



(a) An mGPC is used to generate intense light for particle sorting. (b) Intensity profiles are generated using two LCoS pico-projectors as binary phase input and matched phase filter: (c) without the filter, (d) using phase disks as the input phase pattern and (e) using an optimized binary input phase and matched filter.

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Researchers

Andrew R. Bañas, **Darwin Palima** and **Jesper Glückstad** (jesper.gluckstad@fotonik.dtu.dk)
Technical University of Denmark in Kongens Lyngby.

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PHASE CONTROL

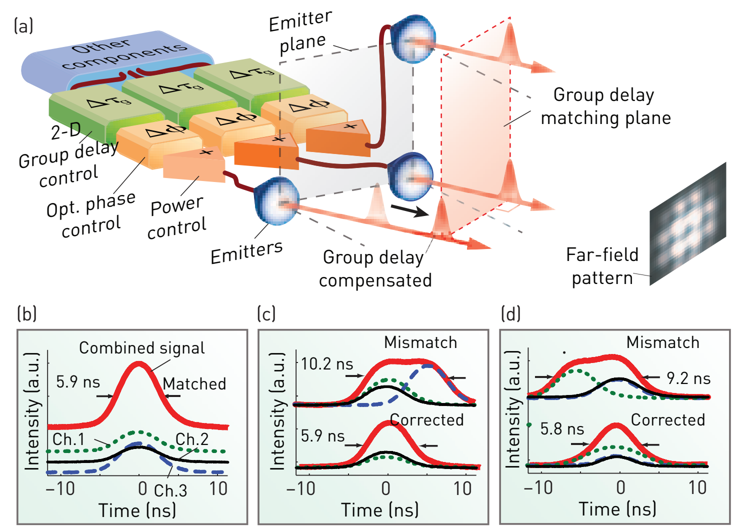
A Slow-Light Laser Radar (**SLIDAR**)

Light detection and ranging (LIDAR) is used in a variety of remote sensing applications, such as measuring atmospheric properties, detecting chemical and biological agents and surveilling vehicles.[1] The key performance parameters of a LIDAR system include its transverse and longitudinal resolutions.

Similar to imaging systems, the far-field transverse resolution of LIDAR depends on the aperture size of its emitter. Recently, multi-aperture systems have been studied for various applications, such as high-performance telescopes and high-power lasers. Compared to a single large aperture, multi-aperture systems can achieve a larger effective aperture size—in other words, fine far-field transverse resolution, without the need for heavy and slow opto-mechanical components.

Since the signals from different emitters need to be coherently combined in the far-field, a multi-aperture LIDAR requires precise optical phase control of every emitter's output. Furthermore, a LIDAR working in a pulsed mode faces an additional challenge. When the beam is steered far off from the direction normal to the emitter array plane, the emitters at one side of the system become closer to the far-field target than those on the other. Thus, the signal pulses sent from different emitters may no longer overlap in time when they reach the far field. Such a group delay mismatch will degrade both the longitudinal and transverse resolutions. Thus, it is crucial to dynamically correct the group delay mismatch such that the pulsed signals emitted from different channels are always aligned properly in time when they reach the far field.

Earlier this year, we proposed and demonstrated a multi-aperture slow-light laser radar (SLIDAR) system.[2] We incorporate two independent fiber-based tunable slow light mechanisms, namely dispersive delay and stimulated Brillouin scattering (SBS) slow light, to realize dynamic group delay compensation while the system scans in two orthogonal directions.[3,4] We also use a heterodyne locking scheme to control the optical phase of the output of each emitter.



(a) A SLIDAR system capable of 2-D beam steering; normalized time traces of the returned signal when the system is (b) pointing on-axis, (c) tilted in the *x* direction, and (d) tilted in both the *x* and *y* directions. The thick red line is the combined signal, while the thin lines are the signal from three individual channels.

We use three emitters arranged in a right-angle 2-D pattern. Such an arrangement contains all of the conceptual difficulties of a multi-channel system. Specifically, it requires simultaneous implementation of two types of slow light mechanisms as well as optical phase locking.

When the system is pointing at off-axis directions, the group delay mismatch will result in significant signal broadening, indicating serious degradation in longitudinal and transverse resolutions. When the 2-D group delay control units are turned on, the mismatch is compensated well and there is no pulse broadening in the returned signal. With our demonstration of all the key techniques, the implementation of a full-fledged SLIDAR system becomes straightforward. OPN

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Researchers

Zhimin Shi (zshi@optics.rochester.edu), **Aaron Schweinsberg** and **Joseph E. Vornehm**
The Insitute of Optics, University of Rochester, Rochester, N.Y., U.S.A.

Robert W. Boyd
The Insitute of Optics, University of Rochester, and University of Ottawa, Ontario, Canada.

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