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Fast beam steering and agile wavefront control with an optical phased array

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ABSTRACT

Optical phased arrays (OPAs) are a solid-state device able to manipulate the distribution of optical power without the use of mechanical beam steering systems and have potential applications in free-space laser communications, target acquisition and tracking, and interferometry. Here we present a scalable OPA and digital control architecture capable of steering a laser beam at MHz frequencies, and having arbitrary control over the beam wavefront.

Keywords: optical phased array, field-programmable gate array, fast steering, wavefront control, phase sensing

1. INTRODUCTION

Laser beam steering systems are crucial to technologies such as light detection and ranging (LIDAR), remote sensing, and communications. Mechanical beam steering technologies are often limited in their steering bandwidth and scan patterns due to inertia of the components. These systems are also subject to mechanical wear which makes them a high-risk option for applications such as onboard spacecraft. Solid-state OPAs are not limited by inertia or mechanical wear, making them an attractive alternative for systems that require robust and agile beam steering. OPAs work by interfering multiple separate emitters to form a coherent and contiguous optical wavefront. By controlling the phase of each emitter in the array, it is possible to steer the beam in the far-field.¹ In this talk we present the design of a scalable digitally controlled OPA. We describe the experimental demonstration of the phase sensing and control system, and progress towards fast (MHz) steering speeds.

2. METHODS AND TECHNIQUE

The OPA presented here uses EOMs to continuously control the phase of each element in the array, enabling arbitrary control of the wavefront and MHz bandwidth beam steering. Phase sensing and control is performed on a field-programmable gate array (FPGA). The phases of individual emitters are measured using digitally enhanced heterodyne interferometry (DEHI)² which uses pseudo-random bit sequences (PRBS) encoded onto each emitter channel to distinguish and measure the phase of that emitter.

Light from a laser is split and guided through EOMs which apply a PRBS code, steering signal, and phase synchronization feedback to each channel, and launched into free-space (Fig. 1). A local oscillator channel is frequency shifted using an acousto-optic modulator for heterodyne detection at the photodetector. In the FPGA, the PRBS codes are demodulated and the signals are sent to separate phasemeters that measure the phase of each emitter and provide a control signal to the EOMs to stabilize the relative phase of the emitters against external thermal and acoustic noise.

The feedback bandwidth of the control system is limited to a few kHz by the time delay through the FPGA. To achieve MHz steering speeds, steering signals above the bandwidth of the control loop are applied out-of-loop by the controllers. To avoid the control loop trying to compensate for the steering signal the digital low-pass filters in the phasemeters are configured to reject the steering signal frequencies. Steering of the beam at frequencies within the bandwidth of the controller is simply achieved by sweeping the error point that the controller is trying to lock to.

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