steering assemblies for coarse beam pointing as well as to mitigate pointing errors due to, for example, jitter of the platform to which it is attached. These mechanical assemblies add considerable weight, are frequently bulky, and often consume high electrical power.

[0007] The description provided in the background section should not be assumed to be prior art merely because it is mentioned in or associated with the background section. The background section may include information that describes one or more aspects of the subject technology.

SUMMARY

[0008] In a first aspect, a multi-aperture optical system is provided that comprises a photonic integrated circuit, a spacer substrate coupled to the photonic integrated circuit, a plurality of optical cells, a beam combiner, and a photodetector coupled to the beam combiner. The photonic integrated circuit, the spacer substrate, the plurality of optical cells, the beam combiner, and the photodetector are integrated as a single monolithically formed optical head. Each optical cell includes a focusing optical element formed on the spacer substrate and configured to receive the light incident on the optical cell, and focus the light through the photonic integrated circuit and onto a folding element. The folding element is integrated into the photonic integrated circuit to couple light incident on the optical cell into a waveguide. The waveguide is integrated into the photonic integrated circuit, coupled to the phase shifter, and configured to transport the light reflected by the folding element through a phase shifter. The phase shifter is coupled to the focusing optical element, and configured to shift a phase of an optical signal received by the focusing optical element. The beam combiner is coupled to the phase shifters, and configured to combine light output from the phase shifters. The photodetector receives the combined light output from the beam combiner and outputs a corresponding signal.

[0008a] In a second aspect, a method of manufacturing a multi-aperture optical system is provided that comprises fabricating a plurality of optical cells onto a photonic integrated circuit, where each optical cell includes a folding element, a focusing optical element, a phase shifter, and a waveguide coupled to the phase shifter. The fabricating comprises, for each optical cell, integrating a folding element into the photonic integrated circuit, embedding the phase shifter in the photonic integrated circuit, fabricating the waveguide on or in the photonic integrated circuit, coupling the waveguide to the phase shifter, and fabricating the focusing optical element on a spacer substrate coupled to the photonic integrated circuit above the folding element. The method

further includes fabricating a beam combiner and a photodetector on the photonic integrated circuit, the photodetector being coupled to the beam combined and the beam combiner coupled to each phase shifter. The photonic integrated circuit, the spacer substrate, the plurality of optical cells, the beam combiner, and the photodetector are integrated as a single monolithically formed optical head.

[0009] In one or more implementations, a method of manufacturing a multi-aperture optical system is provided that includes fabricating a plurality of optical cells on the photonic integrated circuit, where each optical cell includes a folding element, a focusing optical element, a phase shifter, and a waveguide coupled to the phase shifter. The fabricating includes, for each optical cell, integrating a folding element into the photonic integrated circuit, embedding the phase shifter in the photonic integrated circuit, fabricating the waveguide on the photonic integrated circuit, coupling the waveguide to the phase shifter, and fabricating the focusing optical element on a spacer substrate coupled to the photonic integrated circuit above the folding element. The method further includes fabricating a beam combiner and a photodetector on the photonic integrated circuit, and coupling a controller to the photodetector to control phase shifts of each phase shifter based on a signal output from the photodetector. The photodetector is coupled to the beam combiner and the beam combiner coupled to each phase shifter. The photonic integrated