SYSTEMS AND METHODS FOR SCALING ELECTROMAGNETIC APERTURES, SINGLE MODE LASERS, AND OPEN WAVE SYSTEMS

Tech ID: 32678 / UC Case 2022-077-0

PATENT STATUS

Country	Type	Number	Dated	Case
Patent Cooperation Treaty	Published Application	WO 2024/043944	02/29/2024	2022-077

BRIEF DESCRIPTION

The inventors have developed a scalable laser aperture that emits light perpendicular to the surface. The aperture can, in principal, scale to arbitrarily large sizes, offering a universal architecture for systems in need of small, intermediate, or high power.

The technology is based on photonic crystal apertures, nanostructured apertures that exhibit a quasi-linear dispersion at the center of the Brillouin zone together with a mode-dependent loss controlled by the cavity boundaries, modes, and crystal truncation. Open Dirac cavities protect the fundamental mode and couple higher order modes to lossy bands of the photonic structure. The technology was developed with an open-Dirac electromagnetic aperture, known as a Berkeley Surface Emitting Laser (BKSEL).

The inventors demonstrate a subtle cavity-mode-dependent scaling of losses. For cavities with a quadratic dispersion, detuned from the Dirac singularity, the complex frequencies converge towards each other based on cavity size. While the convergence of the real parts of cavity modes towards each other is delayed, going quickly to zero, the normalized complex free-spectral range converge towards a constant solely governed by the loss rate of Bloch bands. The inventors show that this unique scaling of the complex frequency of cavity modes in open-Dirac electromagnetic apertures guarantees single-mode operation of large cavities.

The technology demonstrates scaled up single-mode lasing, and confirmed from far-field measurements. By eliminating limits on electromagnetic aperture size, the technology will enable groundbreaking applications for devices of all sizes, operating at any power level.

BACKGROUND

Single aperture cavities are bounded by higher order transverse modes, fundamentally limiting the power emitted by single-mode lasers, as well as the brightness of quantum light sources. Electromagnetic apertures support cavity modes that rapidly become arbitrarily close with the size of the aperture. The free-spectral range of existing electromagnetic apertures goes to zero when the size of the aperture increases. As a result, scale-invariant apertures or lasers has remained elusive until now.

Surface-emitting lasers have advantages in scalability over commercially widespread vertical-cavity surface-emitting lasers (VCSELs). When a photonic crystal is truncated to a finite cavity, the continuous bands break up into discrete cavity modes. These higher order modes compete with the fundamental lasing mode and the device becomes more susceptible to multimode lasing response as the cavity size increases.

SUGGESTED USES

Scalable lasers will have many Lidar applications, such as for self-driving cars, cabin sensing, consumer electronics such as smartphones, optical communications (long-haul, medium distance, and short distance interconnects), medical devices, and more.

- Automotive Lidar for self-driving vehicles and robots
- In cabin sensing

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INVENTORS

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OTHER INFORMATION

KEYWORDS

lidar, laser aperture

CATEGORIZED AS

- **Optics and Photonics**
  - All Optics and Photonics
- **Communications**
  - Optical
- **Computer**
  - Other
- **Engineering**
  - Engineering
- **Imaging**
  - Remote Sensing
- **Medical**
  - Devices
- **Nanotechnology**
  - NanoBio
- **Research Tools**
  - Other
- **Security and Defense**
  - Screening/Imaging

- Consumer electronics and smartphones for face recognition, virtual reality etc.
- Optical communications and optical interconnects
- Information and communications technology
- Light based manufacturing
- Medical devices for sensing, surgery etc.
- Satellite communications via optical links
- Laser machining
- Optical vortex generators for cell trapping and manipulation
- Laser displays
- Sensing, face-recognition, surgery, and remote surgery
- Biosensing needing integrated and compact coherent sources
- Tweezers for object trapping and manipulation
- Compact source for mobility applications and lidars
- Coherent source for trapping and entangling qubits and for quantum computing
- Optical antennas for enhanced and directive emission of classical and quantum light
- High power arrays for the propulsion of light sails

The invention can be:

- integrated in silicon or other CMOS devices for light emission out of the chip
- used to manipulate cells and biological substances for trapping
- used in application for lidars especially where the efficiency and the weight are critical, such as in mobility applications or applications in laser surgery where the laser needs to be inserted in a small volume
- directly integrated with sensors for environmental monitoring as a single laser or as an array of lasers
- used to implement electronically controlled beam steering for lidars by placing an array of the proposed lasers in the focal plane of an imaging system
- inserted in a pn junction for making electrically pumped single mode lasers
- used with dye molecule for lasing using organic materials
- directly pumped optically as a diode.
- used to control electromagnetic emission from materials.
- used to scale up any open-system based on waves such as acoustic, quantum, or electronic systems

ADVANTAGES

Current lasers all fail at a relatively small scale on the order of tens of microns by tens of microns, necessitating multimode systems. In contrast, this technology offers a single, arbitrarily scalable aperture laser with many advantages.

- thin
- compact
- lightweight
- efficient, because power is emitted from all material in the aperture
- the fundamental mode depletes gain for other modes

- **Sensors & Instrumentation**
  - Biosensors
  - Medical
  - Other
  - Physical Measurement
  - Position sensors
- **Transportation**
  - Aerospace
  - Automotive

RELATED CASES

2022-077-0

- can be pumped both electrically and optically
- can be manufactured with conventional fabrication techniques such as CMOS nanofabrication; the technology contains structures on the order of the wavelength or smaller
- more scalable than any other single aperture lasers, offering a singular solution for small size, weight, and power (SWAP) devices
- can be implemented in any frequency, ranging from microwaves, terahertz, infrared, optics, and beyond

RELATED MATERIALS

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