External Cavity Laser Based Upon Metasurfaces

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OTHER INFORMATION

KEYWORDS

Vertical-external-cavity-surface-emitting-laser, VECSEL, terahertz, quantum cascade laser, metasurface

CATEGORIZED AS

- **Optics and Photonics**
  - All Optics and Photonics
- **Communications**
  - Internet
  - Networking
  - Other
- **Imaging**
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  - Other
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RELATED CASES

2015-797-0

SUMMARY

UCLA researchers in the Department of Electrical Engineering have developed a novel approach for terahertz (THz) quantum-cascade (QC) lasers to achieve scalable output power, high quality diffraction limited, and directive output beams.

BACKGROUND

It is challenging for many types of semiconductor lasers to achieve a symmetric, directive, diffraction-limited, and non-astigmatic high quality beam. This is particularly true as the waveguide size is increased to scale up the power, since multiple transverse mode oscillations can lead to sub-optimal beam quality as well as modal instabilities. Beam quality poses a more difficult challenge for terahertz (THz) quantum-cascade (QC) lasers because THz QC-lasers almost exclusively use sub-wavelength metallic and/or plasmonic waveguides, which leads to highly divergent beams with large side-lobes unless special surface-emitting or antenna coupled geometries (i.e. 2nd order distributed feedback (DFB) and photonic crystal cavities, arrays of 2nd order DFBs, and end-fire 3rd oder DFBs) are used. Strategies for further beam narrowing are limited as the beam divergence increases as the square root of the device length.

The vertical-external-cavity surface-emitting-laser (VECSEL) approach has demonstrated to deliver near diffraction-limited beam quality even at high output powers when used in the visible and near-infrared spectral range. However, it has been impossible to implement VECSEL for QC-lasers since the intersubband selection rule prevents interaction of the gain medium with surface incident beam. Meanwhile, THz QC-lasers that operate with both high output power and excellent beam quality are sorely needed for a range of spectroscopy and imaging applications.

INNOVATION

Researchers at UCLA have developed a THz QC-VECSEL formed by an active metasurface reflector and a flat output coupler reflector. The innovative active metasurface reflector is comprised of a sparse array of antenna-coupled THz QC-laser active sub-cavities allowing scalable power combining. A prototype of this THz QC-VECSEL is able to produce approximately 6 mW of peak power, a highly directive beam with approximately 5 degree full width half max divergence angle, and a close to Gaussian profile.

APPLICATIONS

- THz laser sources are useful for THz imaging and spectroscopy applications:
  - Spectroscopy and multi-spectral imaging of materials such as explosives and drugs
  - Non-destructive evaluation imaging of films and coatings for industrial process control or corrosion detection
- Other possible applications include:
  - Biomedical THz imaging
  - THz communications (i.e. civil aviation and military applications based on THz radiation’s superior performance under poor weather conditions)
  - THz imaging for security screening (i.e. enhancement of chemical, biological, nuclear, radiological and/or explosive detection)
  - Detection of astrophysical objects

ADVANTAGES

- The QC-VECSEL can generate high quality beams with large powers in continuous-wave mode in the THz frequency range, where existing laser sources have problems achieving.
- Similar concept using active metasurfaces can be applied for utilities in the mid-infrared frequency ranges as well.
- The metasurface reflector forms part of the external laser cavity such that multiple THz QC-laser sub-cavities are locked to a high quality (high Q) cavity mode, allowing for scalable power combining.
- Near-diffraction-limited circular TEM00 beams are sustained by external cavities and spatial filtering to prevent higher order mode oscillation.
- The antenna metasurface is strongly coupled to radiation for high optical coupling efficiency.

- Sparse areal coverage of the active material in the metasurface reduces the areal power dissipation density over larger active areas for high power and good cw performance.
- Enables external cavity laser tuning schemes.
- The antenna coupled metasurface can be engineered to provide spatially dependent gain, phase, or polarization response. This can enable more efficient model/gain coupling, reflectarray focusing for compact cavities, or beams with customized polarization.

STATE OF DEVELOPMENT

Prototype of the described THz QC-VECSEL has been successfully tested.

PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Issued Patent	9,728,930	08/08/2017	2015-797

RELATED MATERIALS

- Xu, L., Curwen, C.A., Hon, P.W.C., Chen, Q., Itoh, T., Williams, B.S. (2015). Metasurface external cavity laser. Applied Physics Letters, 107, 221105-1 – 221105-5
- Xu, L., Curwen, C.A., Hon, P.W.C., Itoh, T., Williams, B.S. (2016). Terahertz quantum cascade VECSEL. Vertical External Cavity Surface Emitting lasers (VECSELs) VI, SPIE Proceedings, 9734, 97340G-1 – 97340G-6

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