OSA Lasers in Manufacturing Technical Group

Newsletter

winter 2016

This is the first issue of the newsletter dedicated to the members of Lasers in Manufacturing Technical Group. In every issue will try addressing the most recent news related to our group and highlight relevant research topics.

In this issue Yufeng Li update on the results of the technical group survey. Following this survey the committee decided to select papers of interest from six most topical areas. We are starting with ultrafast laser processing. Athanasiou Christos Edouardos gladly agreed in selecting the relevant papers and highlighting importance and recent trends in this field.

by Martynas Beresna, Chair of Lasers in Manufacturing Technical Group

UPDATE ON TECHNICAL GROUP SURVEY

Back in July, we sent out a questionnaire asking about your expectations of our technical group and preferred activities. For members who were kind enough to respond and indicate your choices, we appreciate your support.

Based on the feedback we've received, a vast majority (64%) of you expect to "discover and learn about new directions and current trends," and 56% of you prefer a "regular newsletter highlighting research topics and applications." When asked about the most relevant topics, the answers are almost equally divided between "key advances in industry" and "emerging new applications", while "hot research topics" got the remaining 20% of the votes.

The choices of technical topics of interest varied widely from member to member, but overall we've identified the following 6 topics as the most popular:

(1) Ultrafast laser material processing;
(2) Laser-Based 3D Printing and Additive Manufacturing;
(3) Industrial high-power lasers (Diode Lasers, DPSS & Fiber Lasers);
(4) Laser-Based Micro and Nano Machining;
(5) Laser-Based Glass Processing;
(6) Novel Applications of Lasers in Manufacturing;

by Yufeng Li, Vice Chair of Lasers in Manufacturing Technical Group

SELECTED PUBLICATIONS

Normally it is matter that determines what happens to light by controlling its propagation speed, phase, direction and etc. However, at extremely high intensities, easily accessible with tightly focused ultrashort laser pulses, the roles of light and matter are reversed – light determines what happens to matter. This opens doors into things that could not be achieved with conventional manufacturing tools. Recent years saw rapid development of ultrashort laser systems and their transition from solely research environment into solid industrially viable manufacturing tool.

Core applications of this powerful three dimensional manufacturing method –the so-called femtosecond laser processing- yield in the micro-processing of materials with an ultimate goal to alter the properties of metals, semiconductor or dielectrics so that they can be used for novel applications. Below we selected articles representing recent developments including micro-electric systems **[Hou]**, resonators **[Cheng]**, sensors **[Kashyap]**, and optical components and photonic devices **[Herkommer, Eaton, Shade]**.

by Athanasiou Christos Edouardos

High-level integration of three-dimensional microcoils array in fused silica

C. Shan, F. Chen, E. Q. Yang, Y. Li, H. Bian, J. Yong, and X. Hou

- OPTICS LETTERS 40, 4050-4053 (2015)

Rapid and facile creation of three-dimensional (3D) microcoils array in a "lab-on-a-chip" platform is a big challenge in micromachining. Here we report a method based on an improved femtosecond-laser wet-etch (FLWE) technology and metal-microsolidifying process for the fabrication of 3D microcoils array inside fused silica. Based on this approach, we fabricated microcoil arrays such as 3 × 3 O-shaped microcoils array and 4 × 4 liner microcoils array. By injecting highmelting-point alloy, the electrocircuit of microcoils array can hardly be disconnected. The microcoils array also exhibits good uniformity and a high integration level. It shows promise as a real application device.

Fabrication of an integrated high-quality-factor (high-Q) optofluidic sensor by femtosecond laser micromachining

J. Song, J. Lin, J. Tang, Y. Liao, F. He, Z. Wang, L. Qiao, K. Sugioka, and Y. Cheng

- OPTICS EXPRESS 22, 14792-14802 (2014)

We report on fabrication of a microtoroid resonator of a high-quality factor (i.e., Q-factor of ~3.24 × 106 measured under the critical coupling condition) integrated in a microfluidic channel using femtosecond laser three-dimensional (3D) micromachining. Coupling of light into and out of the microresonator has been realized with a fiber taper that is reliably assembled with the microtoroid. The assembly of the fiber to the microtoroid is achieved by welding the fiber taper onto the sidewall of the microtoroid using CO2 laser irradiation. The integrated microresonator maintains a high Q-factor of 3.21 × 105 as measured in air, which should still be sufficient for many sensing applications. We test the functionality of the integrated optofluidic sensor by performing bulk refractive index sensing of purified water doped with tiny amount of salt. It is shown that a detection limit of ~1.2 × 10−4 refractive index unit can be achieved. Our result showcases the capability of integration of high-Q microresonators with complex microfluidic systems using femtosecond laser 3D micromachining.

Toward the integration of optical sensors in smartphone screens using femtosecond laser writing

J. Lapointe, F. Parent, E. Soares de Lima Filho, S. Loranger, and R. Kashyap

OPTICS LETTERS 40, 5654-5657 (2015)

We demonstrate a new type of sensor incorporated directly into Corning Gorilla glass, an ultraresistant glass widely used in the screen of popular devices such as smartphones, tablets, and smart watches. Although physical space is limited in portable devices, the screens have been so far neglected in regard to functionalization. Our proof-of-concept shows a new niche for photonics device development, in which the screen becomes an active component integrated into the device. The sensor itself is a near-surface waveguide, sensitive to refractive index changes, enabling the analysis of liquids directly on the screen of a smartphone, without the need for any add-ons, thus opening this part of the device to advanced functionalization. The primary function of the screen is unaffected, since the sensor and waveguide are effectively invisible to the naked eye. We fabricated a waveguide just below the glass surface, directly written without any surface preparation, in which the change in refractive index on the surface–air interface changes the light guidance, thus the transmission of light. This work reports on sensor fabrication, using a femtosecond pulsed laser, and the light-interaction model of the beam propagating at the surface is discussed and compared with experimental measurement for refractive indexes in the range 1.3–1.7. A new and improved model, including input and output reflections due to the effective mode index change, is also proposed and yields a better match with our experimental measurements and also with previous measurements reported in the literature.

Ultra-compact on-chip LED collimation optics by 3D femtosecond direct laser writing

S. Thiele, T. Gissibl, H. Giessen, and A. M. Herkommer

OPTICS LETTERS 41, 3029-3032 (2016)

By using two-photon lithographic 3D printing, we demonstrate additive manufacturing of a dielectric concentrator directly on a LED chip. With a size of below 200 µm in diameter and length, light output is increased by a factor of 6.2 in collimation direction, while the emission half-angle is reduced by 50%. We measure excellent form fidelity and irradiance patterns close to simulation. Additionally, a more complex shape design is presented, which exhibits a nonconventional triangular illumination pattern. The introduced method features exceptional design freedoms which can be used to tailor high-quality miniature illumination optics for specific lighting tasks, for example, endoscopy.

Diamond photonics platform enabled by femtosecond laser writing

B. Sotillo, V. Bharadwaj, J. P. Hadden, M. Sakakura, A. Chiappini, T. T. Fernandez, S. Longhi, O. Jedrkiewicz, Y. Shimotsuma, L. Criante, R. Osellame, G. Galzerano, M. Ferrari, K. Miura, R. Ramponi, P. E. Barclay, S. M. Eaton

SCIENTIFIC REPORTS 6, 35566 (2016)

Diamond is a promising platform for sensing and quantum processing owing to the remarkable properties of the nitrogen-vacancy (NV) impurity. The electrons of the NV center, largely localized at the vacancy site, combine to form a spin triplet, which can be polarized with 532 nm laser light, even at room temperature. The NV's states are isolated from environmental perturbations making their spin coherence comparable to trapped ions. An important breakthrough would be in connecting, using waveguides, multiple diamond NVs together optically. However, still lacking is an efficient *photonic fabrication method for diamond akin to the photolithographic methods that have revolutionized silicon photonics. Here, we report the first demonstration of three dimensional buried optical waveguides in diamond, inscribed by focused femtosecond high repetition rate laser pulses. Within the waveguides, high quality NV properties are observed, making them promising for integrated magnetometer or quantum information systems on a diamond chip.*

Cladding waveguide gratings in standard single-mode fiber for 3D shape sensing

C. Waltermann, A. Doering, M. Köhring, M. Angelmahr, and W. Schade

OPTICS LETTERS 40, 3109-3112 (2015)

Femtosecond laser pulses were used for the direct point-by-point inscription of waveguides into the cladding of standard single-mode fibers. Homogeneous S-shaped waveguides have been processed as a bundle of overlapping lines without damaging the surrounding material. Within these structures, FBGs have been successfully inscribed and characterized. A sensor device to measure the bending direction of a fiber was created by two perpendicular inscribed cladding waveguides with FBG. Finally, a complete 3D shape sensor consisting of several bending sensor planes, capable of detecting bending radii even below 2.5 cm is demonstrated.

EXECUTIVE COMMITTEE

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