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光科学特別実習　報告書

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Banner of LPM2021 (http://www.jlps.gr.jp/lpm/lpm2021/)

In this report I will share my experience at the 22nd International Symposium on Laser Precision Microfabrication (LPM2021). This annual conference is where scientists and engineers working in the field of photonics gather to share leading-edge fabrication technologies and discoveries providing insight into the complex phenomena of laser processing. Although it is custom for the LPM to be held in different nations such as Japan, Scotland, Germany and the USA, this year's conference was held online due to the COVID-19 crisis. Nevertheless, many enthusiastic researchers showed up to share their latest results, and it was an exciting 4 days of intensive learning and communication. Here I will share a detailed report on the newest trends in both fundamental research and application that I learned by listening to various presentations. I had the honor to hold discussions (including light Q&A's) with all of the presenters mentioned in this report.

[Trends in fundamental research]
As popular as laser microfabrication is as an industrial tool, the mechanism of the microstructure formation itself is still a target of intensive research. Understanding the physical picture behind high intensity laser-matter interaction is key to realizing novel designs with higher precision and repeatability.

One common approach to this objective is to clarify the exact effect of certain laser parameters on the final processing results. For example, Prof. David Grojo of Aix-Marseille University, shared his latest research on the wavelength-dependency on the morphology of laser-drilled holes, revealing that the commonly referred idea of "longer wavelength = smaller holes" is a misconception, and that shorter wavelength sources (such as UV) are still valuable for producing holes with better resolution [1]. Prof. Grojo is part of the LP3 Institute, a project partner of Laserlab Europe and a leading academic laboratory in the field of photonic processing.

Another trending approach in fundamental research is time-resolved measurement, where the researcher exploits a laser pulse as short as the main pulse itself to probe the phenomena following laser-matter contact. This method has shone light on various interesting phenomena such as the transient reflectivity of metal surfaces during laser irradiation [2], the separation of a thin atomic layer due to tensile forces(spallation)[3], both discussed at the conference.

Finally, various groups focus on numerical methods to deduce the laws and forces that drive high-intensity laser-matter interaction. Prof. Leonid Zhigelei, a leading researcher in laser-matter interaction computation, shared a phenomenal numerical method termed the "computational synchrotron", which was applied to simulate the propagation of surface acoustic waves during laser processing [4]. Another memorable talk was by Prof. Atsushi Yamada about the prediction of ultrafast change of optical property of dielectrics using the light-matter simulator SALMON, being a co-developer himself[5].

[Novel applications]

Three trending fields of application that caught my atention in this conference were (1) Direct Laser Interference Patterning(DLIP) and (2) Direct Laser Writing(DLW), and (3) Laser-assisted Crystal Growth.

(1) Direct Laser Interference Patterning(DLIP)

There are countless ways to produce superficial patterns using lasers, a well-known option being the exploitation of LIPSS (Laser-induced Periodic Surface Structure). However, an emerging method that stood out to me most in the conference was DLIP, where two lasers intersect on the surface material to produce an interference pattern, and are scanned across the entire area. This is a simple and robust method for high throughput patterning, and has mostly been investigated by Prof. Lasagni's group of TU Dresden. There were many talks held by the group members on various applications of DLIP, including the production of icephobic surfaces for airplane wings [6].

(2) Direct Laser Writing(DLW)

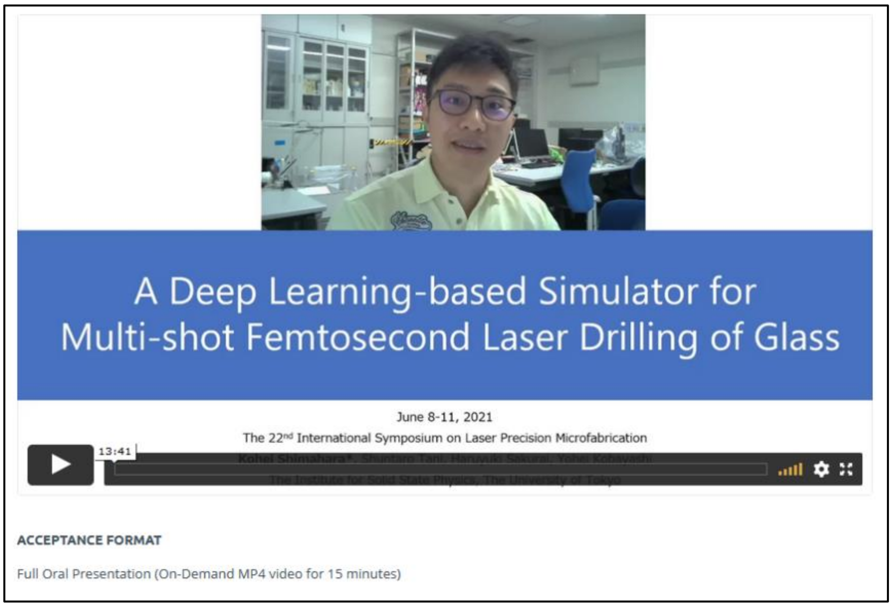
DLW is the method of directly inducing refractive index change within the bulk of the material. Although it was first developed in the 1990s, the scope of application is still rapidly expanding. Prof. Robert Thomson shared some state-of-the-art waveguide structures, including a fan-out with 121 exit channels [7]; Prof. Peter Kazansky shared his achievements of producing spiral phase plates(used for converting beams with linear/circular polarization into vortex beams) and optical storage systems[8] using DLW.

(3) Laser-assisted Crystal Growth

Chemical Vapor Deposition (CVD) is the technique of injecting a stream of hot vapor onto a substrate to form a crystal with the desired composition. Prof. Yongfeng Lu of the University of Nebraska-Lincoln shared a new technique of irradiating the vapor stream of CVD with a near-infrared CW laser, to excite the vibrations of the comprising molecules and assist the deposition process [9]. Using this method, he synthesized a boron-doped diamond crystal necessary for wastewater electrolysis.

[Final Words]

The LPM2021 was held online; most of the talks were pre-recorded videos, and discussions were held live through text. Although there were certain limitations compared to a typical non-virtual conference, I was still able to communicate with many sophisticated researchers whose names I had only seen before in papers, and advertise my own research of deep learning application. I have developed a better understanding of the status quo of the laser microfabrication community, and how I can contribute to this community through my PhD project.



Screenshot of pre-recorded talk by author

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