Domesticating ultrafast laser filamentation in silicon for devising innovative applications

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Abstract

In-volume ultrafast laser direct writing is a proven technique for tailoring the properties of dielectrics (e.g., glasses, polymers) in a three-dimensional, fast, and contactless way. Nevertheless, to date, this technique has no equivalent for silicon, which is the backbone of today's semiconductor industry. The strong limitations preventing the material from the production of internal laser-induced permanent modifications originate from nonlinearities governing the propagation of ultrashort laser pulses in silicon. We have developed solutions to remedy this issue, thus holding promises for countless applications such as contactless 3D integration of photonic and electronic circuits in monolithic silicon, ultrafast laser welding as well as wafer dicing.

After introducing the principles of laser filamentation in silicon, three different laser processing applications will be presented. First, we will demonstrate how elongated modifications can be produced for inscribing low-loss waveguides inside the material. We will then show how the fundamental characterization of filaments is paramount for through-silicon ultrafast laser welding—a technique limited to other material configurations until very recently. Ultimately, we will demonstrate the very first transverse ultrafast laser inscription inside silicon, including material weakening effects sufficient for envisioning innovative wafer dicing methods.

Mini-CV

Maxime Chambonneau received his PhD degree at Aix-Marseille University, France, in 2014 under the supervision of Laurent Lamaignère, Guillaume Duchateau, and Jean-Yves Natoli. He worked as a post-doctoral researcher at LP3 laboratory in Marseille, France, from 2015 to 2018, in David Grojo's group. From 2018, he is a post-doctoral researcher at the Institute of Applied Physics in Jena, Germany, in Stefan Nolte's group. The results of his work are published in 30 peer-reviewed articles and book contributions, 3 international patents, and 15 invited conference presentations.