Ultrafast Burst-Mode Fiber Lasers: Source Development and Material Processing

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High-precision processing of materials with ultrafast laser pulses is drawing increasing attention as laser sources are finally catching up with industry requirements. In particular, very rapid progress has been achieved in ultrafast fiber lasers, which are popular as a result of their highly repeatable, environmentally robust performance, compact size and possibility to reach high average powers. Meanwhile, our understanding of the rich physics of ultrafast laser-material interaction remains incomplete, wherein lies new opportunities. A particularly exciting possibility concerns the use of groups of pulses, which are extremely closed in time. This changes the interaction physics drastically: A unqualified increase in laser repetition rate would result in severe heat accumulation and other undesirable effects. The average power can be kept at a desirable level by operating the laser in the so-called burst mode, whereby each burst contains a number of closely spaced pulses, benefiting from accumulative effects, while the bursts are repeated at much lower repetition rate. Under the right conditions, including keeping average power low enough to prevent excessive heat accumulation, relatively low peak powers for which plasma shielding and similar effects are reduced, ultrafast burst mode can lead to an order-of-magnitude increases in processing speed compared to uniform repetition rate operation of an otherwise identical laser source.

In this contribution, we will review progress in the development of ultrafast burst-mode fiber lasers a well as results from their application to processing of various materials, from metals to semiconductors, dielectrics and various types of tissue. Following their first development [2], ultrafast burst mode fiber lasers have reached average powers of more than 100 W, burst energies of nearly 1 mJ and individual pulse energies of 50 μJ [3-4]. We will present recent results, where intra-burst repetition rate has been increased to 1.7 GHz and average power to 150 W, which allows burst repetition rates in the range of several 100 kHz, up to 1 MHz. For softer targets, such as soft tissue few-watt operation with $\sim$ 10 μJ/pulse and ¡300 fs appear to be nearly optimal. The effect of burst-mode operation has been compared to uniform-mode operation of the same laser for various targets, including metals, transparent dielectrics, semiconductors, piezoelectric ceramics, soft tissues (brain tissue, cornea) and hard tissue (dentine). These results shed further light on the rich physics of the interaction, which will be discussed.

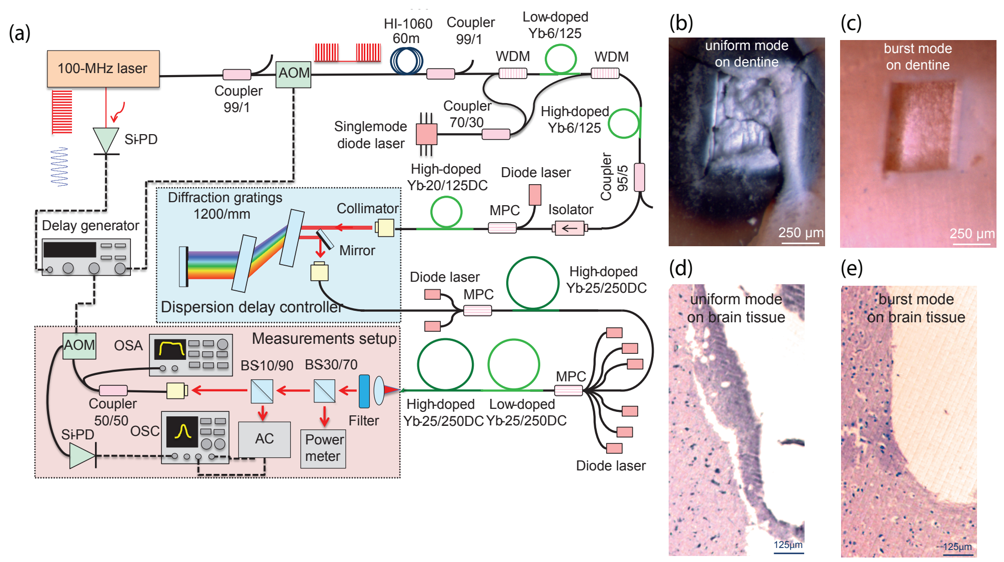

Fig. 1 (a) Setup of the 150-W laser condition. (b) uniform vs. (c) burst mode processing of dentine under otherwise equivalent conditions. (b), (d) uniform vs. (e) burst mode processing of rat brain tissue under otherwise equivalent conditions.

References

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