Digital micromirror devices for laser-based manufacturing

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Abstract

Digital Micromirror Devices (DMDs), containing arrays of around one million individually-controllable ~10μm square mirrors, provide an extremely cost-effective and practical method to modulate the spatial beam profile of a pulsed laser source for both additive and subtractive laser processing and printing. When demagnified by a factor of ~100 in one dimension (hence ~10,000 in area) a ~1mJ/cm^2 laser pulse reflected from the mirrors on the DMD surface that are switched to the 'on' position, attains a fluence of ~10J/ cm^2 at the workpiece, which is more than sufficient to ablate most materials of interest to the laser-manufacturing community.

More familiar in the context of high values of *magnification* by the laser projection industry, reversing the role to use them for equally high values of *demagnification* opens up a wealth of possibilities for ablation, multiphoton polymerization, security marking and fabrication of features that perhaps surprisingly can be well below the wavelength of the laser used. Of key relevance is that very high-resolution patterning can be achieved by a single laser pulse, and step-and-repeat processes, when combined with the refresh rates of the DMD pattern that are currently at the 30kHz level, open up the possibility of processing areas of up to 1cm^2 per second with micron-scale resolution where each ~100μm x 100μm area patterned per pulse can display arbitrary pixelated content.

We will discuss the application of DMD-baser laser processing to the following areas of interest to the laser-manufacturing community:

1. Image projection-based ablation at the micron/sub-micron scale in materials including steel, semiconductors and diamond [1].
2. Multiphoton processing in polymers for single-pulse fabrication of extended 2.5D objects [2].
3. Use of DMD-assisted laser-induced forward transfer (LIFT) for printing of solid phase materials such as polymers and semiconductors in the form of objects such as alphanumeric patterns.
4. Rapid machining of gratings to form bespoke diffractive structures that display multi-coloured (currently up to eight colour) patterns for security coding and marking.
5. The possibility of fabricating arrays with a resolution that is well below the diffraction limit (by using step-and repeat to fill in the pattern using more than one laser pulse).

1. B.Mills, M.Feinäugle, N.Rizvi, R.W.Eason Sub-micron-scale femtosecond laser ablation using a digital micromirror device *Journal of Micromechanics and Microengineering* 2013 Vol.23 pp.035005.
2. B.Mills, J.A.Grant-Jacob, M.Feinäugle, R.W.Eason Single-pulse multiphoton polymerisation of complex structures using a digital multimirror device. *Optics Express* 2013 Vol.21(12) pp.14853-14858.