Technology White Paper - Miracle Plate

Ultra fast laser exposure switching aluminium oxide from hydrophobic to hydrophilic

Ultrafast lasers – the new industrial revolution.

Laser technology has revolutionised litho platemaking. Laser diodes /diode arrays have made the “computer to plate” (CtP) platesetter a common piece of equipment in the printing industry. Originally there was some strong opposition to CtP with concerns about the cost of the lasers and their reliability. Some film suppliers were also understandably worried about having their profitable living disrupted.

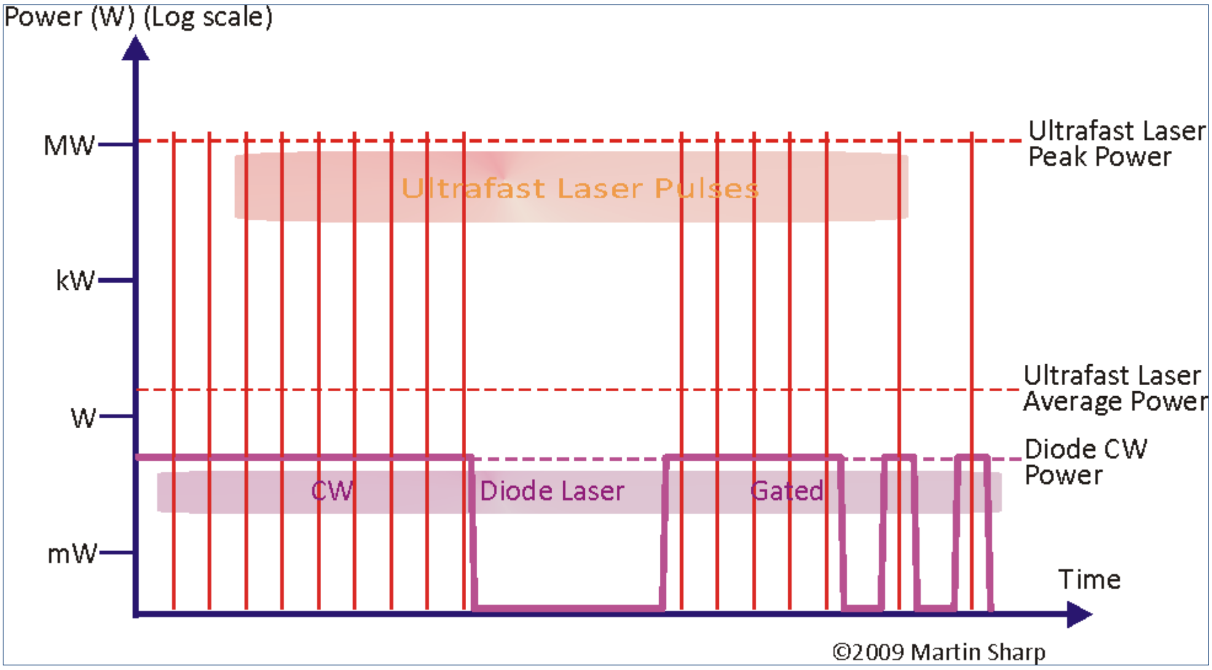
Now CtP is regarded as the norm, not *really* hi-tech any longer. Current plate setter technology is now in a period of incremental development. Many of the main parameters, such as the choice of laser (violet or thermal) are established. Any new improvements are subtle, slow improvements in productivity or cost. No-one really expects seismic changes in what the existing technology can offer. Next year’s platesetter may be 5% faster and *maybe* a little cheaper, but that is as much as might reasonably be expected.

The laser plate setter works by modifying a polymer coating applied to a grained and anodised plate (silver halide coatings have also been used but are now fading in popularity). The necessary reactions to produce the image on the plate are either produced thermally using 830nm IR laser diode sources, or by a photochemical (usually photopolymerisation) reaction using 405nm violet lasers. Both of these laser types were criticised for their initial high cost which critics argued would limit their appeal. Those that were around will remember the heated, often furious opposition to violet diode CTP technology. In hind sight it is clear that much of the debate was more to do with the vested interests of the suppliers rather than the vested interests of the print industry.

Ultrafast Lasers

So called ‘ultrafast’ lasers arrived in the last 10 years or so. Suddenly it was possible to fire pulses of light that only lasted a few tens of *femtoseconds* (1fs = 10^{-15}s). Prior to this, normal (or ‘Q-switched’) lasers were delivering pulses measured in nanoseconds (1ns = 10^{-9}s). The ability to generate pulse lengths between these two, i.e. measured in picoseconds, (1ps = 10^{-12}s) has also been achieved

The first Ultrafast lasers were built on the optical bench and required continual care to maintain their delicate specification. Clark Lasers were one of the first companies to put a “high power” industrial fibre laser on the market (1W average power, offering 1mJ pulses at 1kHz repetition rate). Several more companies introduced models offering a similar performance. In the early 2000’s picosecond lasers become available. Huge attention was given to making these lasers as reliable as possible, initially they needed very careful handling and expert re-alignment. However these lasers are now appearing in 24/7 industrial applications, but usually in high technology environments where cleanliness and vibration are already well controlled.



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<u>Figure 1</u>. *The power is in the pulse. Current CTP lasers use relatively low power (100mW) continuous wave (or 'CW') diode lasers that are modulated or gated to produce the image. The gated pulses of such a laser are no more powerful than the CW power itself. With an Ultrafast laser, this is not so - there is no CW power, just the peak power of the pulses. The new Ultra Fast ('UF') lasers generate peak power levels many orders of magnitude over more traditional laser technologies. The peak power levels are high enough to generate novel, previously unseen, changes to the material receiving the laser energy*

Ultrafast laser applications

So why are these lasers so important? The answer lies in the original choice of the title "Ultrafast". Chemical and thermal reactions take place over time scales lasting 10's of picoseconds. But a femtosecond is just one thousandth of a single picosecond. So with such short femtosecond laser pulses, the laser energy is delivered in a time that is much shorter than a chemical reaction would normally take. So what happens then? What happens when a laser can pulse energy into a material in a time so short that normal physical and chemical responses/ reactions don't have the time to react?

To illustrate this, consider the process of laser machining of a metal. Imagine the process of vaporising the metal, the laser irradiates the surface of the metal, extreme heat is formed at the point of exposure, the metal vaporises and ejects both the vapour itself and any surrounding molten metal out of the surface. When this is done with nanosecond (or longer) pulses, there is time for heat to conduct into the surrounding metal and the machining normally leaves a heat affected zone. In fact much of the energy is conducted away from the original point of exposure and into neighbouring areas.

In order for a laser to generate heat on the surface of a material, in this case metals, it takes around 1pS to 10pS for the heat to form. This means that a femtosecond laser pulse lasts for a shorter time than it takes even for heat to form. With femtosecond lasers, the laser beam is absorbed by the electrons flowing around the metal nuclei. This energy is sufficient to turn the area into a plasma that is ejected before there is time to generate any heat. Thus material is removed before heat can be generated in the surrounding metal, giving us one of the stranger scientific discoveries of femtosecond lasers - the creation of “cold ablation”. Before ultrafast lasers had been invented the concept of ‘cold ablation’ would have seemed both impossible and illogical. Now science has not just accepted and embraced this, it is looking for practical ways to exploit these new phenomena. There are many other new and implausible applications of ultrafast lasers that are only now being explored.

The example of cold ablation is given to illustrate what can be achieved with femtosecond lasers. With the miracle-plate technology the laser is imaging a metal-oxide layer (such as aluminium oxide) rather than *pure* metal. So the mechanism that switches hydrophobic alumina into hydrophilic alumina is quite different to cold ablation. With the miracle-plate technology there are other surface-changing phenomena that are occurring and R&D is continuing to fully identify these. The incredible surface energies and electric field effects that come with ultrafast laser exposure definitely play a part......

Terawatt Intensity

Another remarkable feature of Ultrafast lasers is the extreme power intensity that can be generated in the focal spot of the laser beam. Consider the following: A typical 830nm thermal diode used in a typical thermal CTP systems may deliver a pulse of 1nJ, in 10 nano seconds, to a spot size of 20um diameter. This represents a peak intensity of 32kW/cm^2. A 1mJ pulse in 150 *femto* seconds delivered to the same spot size gives 2000TW/cm^2, some **62 billion times more intense**. Since light is an electromagnetic wave this represents a **250,000x** increase in the magnitude of the associated electric field. To physicists, desktop laser application of Terawatt power levels to material surfaces was the stuff of dreams just a few years ago. These power intensities are difficult to comprehend and are only possible due to the incredibly short laser pulsing of femtosecond lasers. Such intense fields interacting with the electrons in the exposed material leads to results such as the cold ablation above, and other interesting phenomena that are only just being discovered. The pulse length is important itself, and some processes are more efficient and easier to perform the shorter the pulse length achieved.

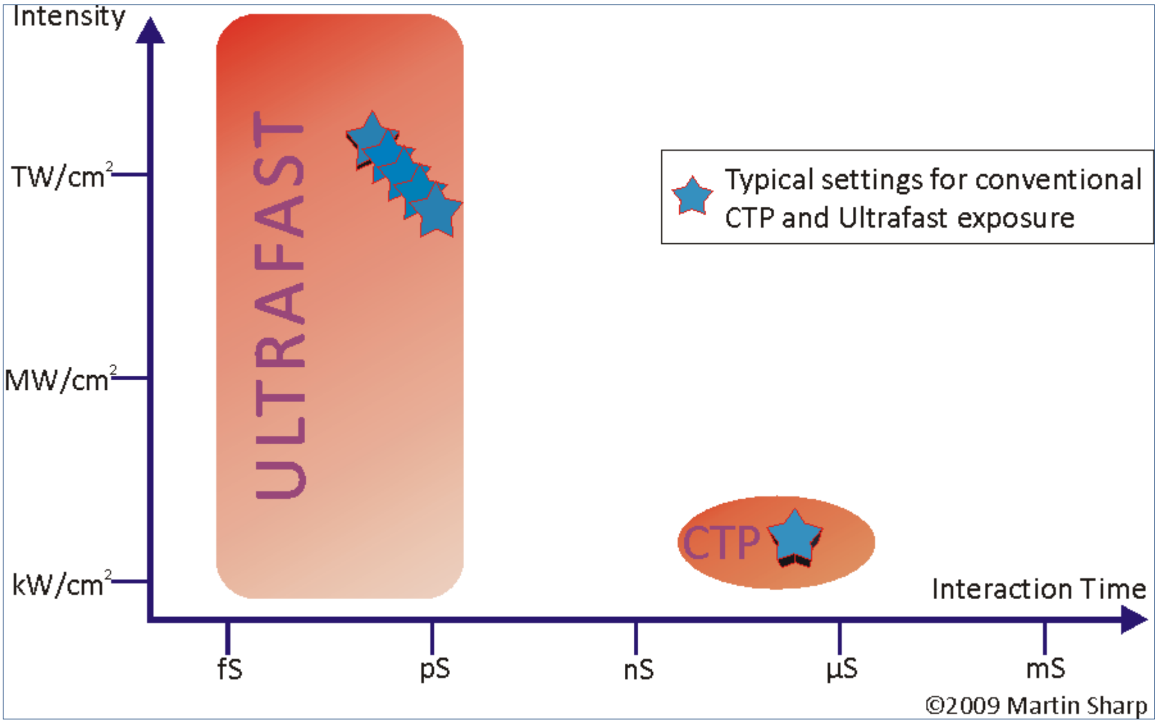

Figure 2. *Ultra Fast lasers deliver large amounts of energy in vanishingly small moments of time. These femto-second pulses deliver energy levels in the Tera Watt/cm2 region. The result is new types of surface modification. Materials can be changed using large, highly controlled, bursts of energy. The duration of these energy pulses is so small that heat has no time to form. The JPI science company have used these ultra fast lasers to change the hydrophobicity of grained and anodised aluminium, raising the possibility of printing plates that can be made from low cost uncoated aluminium*

So the realm of the Ultrafast lasers does indeed offer the promise of materials interactions that could not be previously achieved. It is this possibility that has led to an explosion of interest in these lasers. The Ultrafast laser is opening a whole new area of material science. As new applications are developed, the demand for such lasers increase and the revenue generated can be used to develop more robust and more powerful sources. And with the increased demand there also comes a reduction in cost caused by economies of scale and competition. Despite this, the traditional “solid state” Ultrafast laser is likely to remain quite expensive due to the engineering requirements needed to maintain alignment of the optical subsystems involved. To reduce the cost of ultrafast lasers even further a *new* technology was needed....the fibre laser

The Ultrafast *fibre* laser

The Ultrafast fibre laser has been developed in the last few years. A fibre laser is a laser in which a chemically treated (“doped”) *optical fibre* forms the laser cavity. This “active” fibre is pumped by laser diodes, and there are now several proprietary techniques used to couple the pump light from the laser diodes into the active fibre. With fewer optical components, the fibre laser can be made to generate Ultrafast pulses combined with a rugged design and also come in at around half the price of the solid state equivalents. These prices are likely to drop further, just as prices of early thermal and violet diodes dropped. These ultrafast fibre lasers are also quite compact, electrically efficient and if extra cooling is required it is with simple, low cost, blown air.

The combination of “low” cost and rugged construction make the ultrafast fibre laser the ideal source for more demanding industrial applications. Where the Ultrafast pulses open new fields of science , then this combination has the potential to be the power behind a quantum change in technology, disrupting the existing technology where only incremental change is possible.