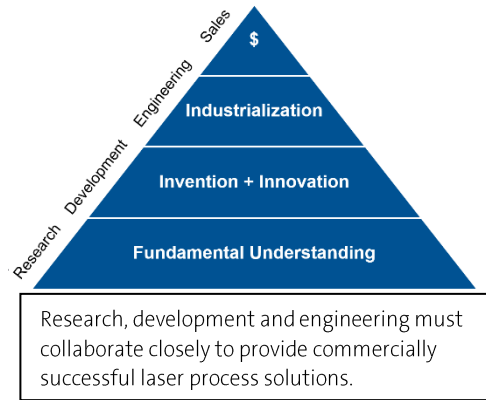


Corning Materials Science

Science Meets Engineering



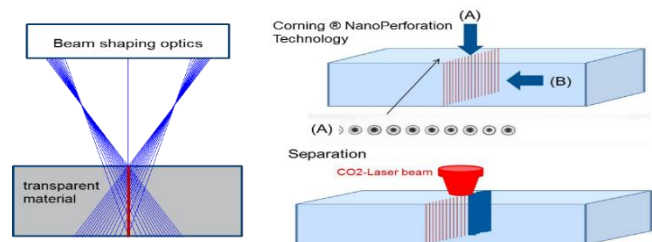
From Proof of Principle to 98.5% Yield of a high-speed laser processing tool

There have been great inventions, discoveries, and developments of sophisticated laser processes in the recent past, many with highly complex lasers and optical setups. To be able to successfully introduce these processes for industrial applications, laser processing tools have to demonstrate reliably their high efficiencies and yields and achieve an attractive cost-per-part value. This requires a fundamental

understanding of laser-material interaction mechanisms and of any factors influencing the process.

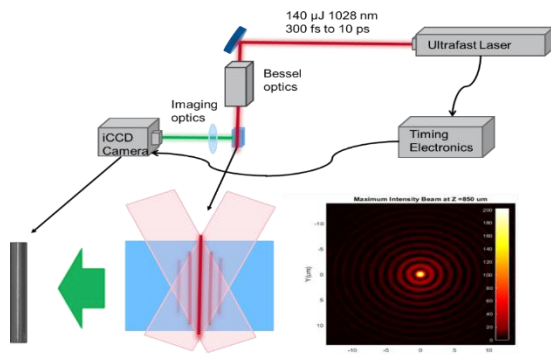
Cutting glass with ultrashort pulsed lasers is a relatively new technology and a good example for what it takes to turn a basic process into a widely adapted processing technology.

The Corning® nanoPerforation cutting process fundamentally differs from former approaches with multi-pass focusing, Kerr self-focusing, or optical confinement. The creation of an optically defined and homogeneous zone with high aspect ratio using non-diffractive beams (e.g. Bessel beams) allows for the instantaneous high intensity interaction



The principal of the patented Corning® nanoPerforation technology.

in a cylindrical zone. With the proper laser parameters, including pulse-width, energy-density, and temporal and spatial profiling, the modification can be optimized so that subsequent exposure to laser-induced thermal stress leads to the precise separation at the desired location. This two-step process can be utilized for most glass compositions.



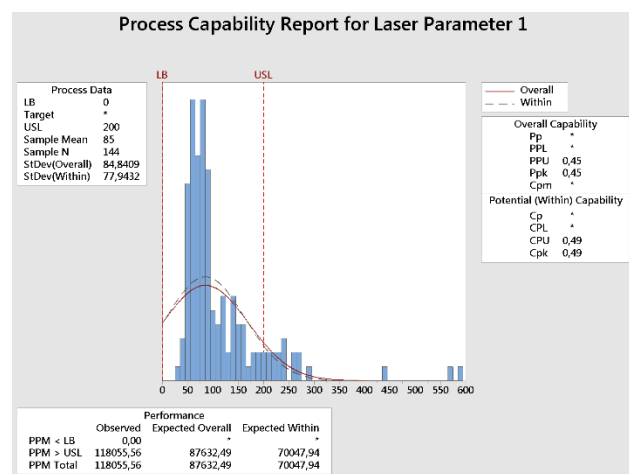
Pump-probe setup shown for an optical setup which creates material modification by exposure to a Bessel beam with high intensity and allows time resolved studies of plasma creation.

The invention of using an ultrashort pulsed non-diffracting beam to cut glass led to an enormous interest in Corning Laser Technologies' capabilities, and within a short period of time, dozens of high-volume production tools were in operation producing millions of parts. The fundamental understanding of the correlation between laser parameters, glass composition, thickness, and geometry, as well as the desired figures of merit like cutting speed, edge strength and quality, was gained by combining our glass scientists and optical physicists with process development.

Systematic process optimization is typically limited, and the boundary conditions in the production environment will be different from the lab. To minimize such differences, Corning Laser Technologies operates production tools in their laser process development laboratories so that the results can more easily be transferred to production tools and thus processes for certain desirable properties can be optimized.

The ability to tightly control and reproduce all process-influencing factors is a prerequisite, not only for the systematic optimization, but also later for a stable process control. Laser properties, beam-delivery components, the kinematic system (belts, linear axes, scanners), as well as auxiliary systems and utilities, need to be monitored constantly. During process development, the process sensitivities are systematically investigated. "Process window"-studies for the most critical parameters determine how tightly these parameters must be controlled and predict, to a certain extent, how stable the process will run.

Most production lines are centrally controlled via a Manufacturing Execution System (MES), also called a Computer-Integrated Manufacturing (CIM). These systems track all relevant parameters of the entire production process. Consequently, a laser processing tool must support all material and data tracking requirements of the system. In general, but in particular during ramp-up, it is very beneficial if the laser process tool contains an independently integrated means for data tracking and process monitoring. "Machine and Condition Monitoring Systems" can be configured to not only record all relevant machine and process properties, but also allow for data input or output to correlate these properties with the measurement results of the customers QA system. The internally collected data, including in-tool inspection results, can



Process capability monitoring during the ramp-up phase

be used for closed-loop process control as well as predictive maintenance or trend indicators.

One of the main advantages of glass cutting with nanoPerforation is the high speed, which also puts high demands on the material handling, transport, motion, and vision system. All systems must keep up with the high speed of the laser process, and at the same time, all systems must exhibit high performance, high reliability, and low maintenance to achieve overall low total cost-of-ownership in relation to the throughput.

The key to success is to optimize throughput while maintaining a stable process with industry standard process capability and yield values. To control a complex process to the required extend, a profound understanding of the fundamental laser-material interaction is necessary, as well as the knowledge of how to optimize the process. Researchers and engineers work closely together so that these inventions can be fundamentally understood and driven to 24/7 robust implementation in order to achieve a 98.5% yield of a high-speed laser processing tool.