

# Ultra Q™ YAG Technology for High-Precision, Low Energy Treatments

A key measure of laser photodisruptor performance is the ability to achieve consistent optical breakdown at an exact location using the lowest level of energy possible. This ensures high precision during surgery, lower incidence of intraocular lens (IOL) pitting, minimal energy exposure of the treated eye and fewer post-treatment complications. Because Ultra Q™ YAG technology effectively achieves these requirements, it enables surgeons to perform advanced YAG applications that require a high level of precision and predictability.

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## Background

Every photodisruptor laser pulse delivered to intraocular structures is designed to create a laser-induced optical breakdown<sup>1</sup>, which is also referred to as plasma. Optical breakdown requires a certain level of power density (irradiance), which is achieved by generating a nanosecond, Q-switched laser pulse and focusing the laser energy to a micron-sized spot. The resulting high electric field strength is sufficient to ionize matter, resulting in plasma formation.

A portion of the plasma develops into an expanding gas bubble, or cavitation bubble, that originates from the site of optical breakdown<sup>2</sup>. The size and lifespan of this cavitation bubble principally depends on the amount of energy deposited into the plasma; however, a typical bubble collapses after a few nanoseconds.

When higher pulse energies are applied (supra-threshold levels), the plasma will form at a larger spot size in an anterior position to the chosen focus point, and will cause the breakdown region to elongate along the beam path<sup>3</sup>. The plasma absorbs almost 90 percent of the laser energy, effectively protecting the retina from high-energy exposure. This effect is called “plasma shielding.”

Despite this shielding action, the expanding plasma and collapsing cavitation bubble still induce spherical pressure waves that travel through the entire eye, hitting not only the posterior capsule, but also other sensitive intraocular structures. The amplitude of these shockwaves increases with laser energy. As a result, pulse energy should be as

small as possible to keep overall energy exposure and shockwave impact at a minimum, and to minimize the risk of possible damaging side effects in the eye.

## Challenges to Creating Reliable Plasma Formation

Optical breakdown is created when power density exceeds a certain threshold value. This threshold is specific for the material in which the plasma is created, and can be influenced by opacities or aberrations in the focusing lens.

All pulsed lasers produce pulses that vary in energy from shot to shot. Pulse energy undergoes further variation due to thermal effects that occur in the YAG laser medium, as well as variations in energy distribution across the laser beam. Because the laser beam is focused to a small spot at the focal plane, these variations cause plasma to form at slightly different coordinates – an effect that can be demonstrated by firing low-energy shots sufficient to cause plasma formation onto a target within a model eye filled with a fluid media.

The uncertainty about placement of the plasma in conventional laser photodisruptors occasionally causes inadvertent pitting of intraocular lenses (IOLs). This is especially true for IOLs composed of newer, soft materials such as silicone and acrylic, which have lower damage thresholds than traditional materials like PMMA.

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## Ultra Q YAG Technology

The Ultra Q system overcomes the problems described above by using advanced technologies in its essential components: the laser cavity, the laser power supply and the microcontroller that manages functionality. In addition, the system features a highly precise aiming beam system that limits maximum focusing tolerance to only 8 microns.

The Ultra Q features a proprietary cavity design that uses a high-performance, solid-state optical Q-switching element fabricated from a material that is far more stable and homogenous than the organic polymer materials used in conventional photodisruptor lasers. In addition the cavity design considers all other critical factors for obtaining a high beam quality:

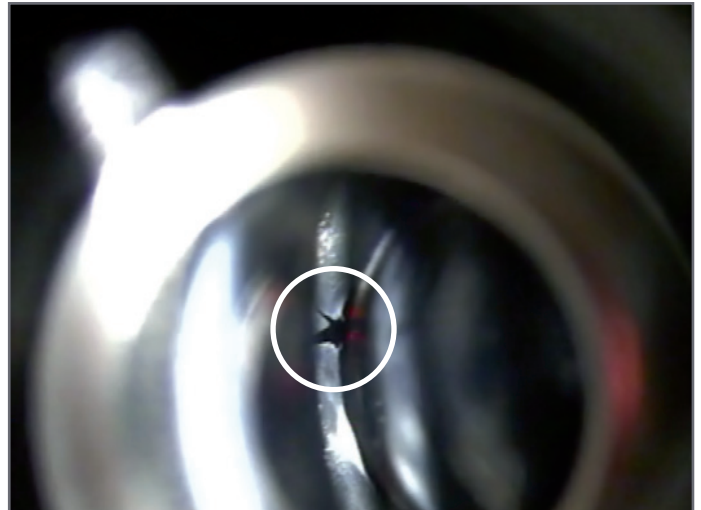
- Optimized resonator design
- Minimized thermal effects
- Use of high quality optical components
- Optimized pump intensity distribution
- Good resonator alignment and low sensitivity of resonator design in regards to mis-alignment.<sup>4</sup>

The excellent beam quality the Ultra Q allows for the beam to be focused to a very small spot at the focal plane, In addition, the system uses diffraction limited optics to optimize energy density. As the beam profile is very homogenous it allows for materially less variation than a conventional laser. The more homogenous the beam is, the easier it is to achieve optical breakdown, even at lower energy levels and to control its positioning.

The power supplies used in most lasers are commercial, off-the-shelf power supplies utilized for capacitor charging applications. With these power supplies, the energy delivered to the laser cavity is related to the voltage that the discharge capacitors are charged to by a square law relationship. In other words, any error in charge voltage translates to that error being squared in cavity energy.

Because the Ultra Q cavity is a passive, Q-switched system, it has a transfer curve of output energy versus input energy that exhibits a series of plateaus resulting from the multiple pulse thresholds – a typical characteristic of a

passively Q-switched cavity design. Each of these plateaus is temperature-dependent, and is set and maintained by way of capacitor voltage. For this reason, the power supply utilized in the Ultra Q has been custom designed to provide a greater level of stability. It is also controlled by a micro-controller that utilizes a complex algorithm to maintain optimum system stability at all times.



**Figure 1:** Precise selective capsulotomy using the Ultra Q system.

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## Conclusion

There are many factors that influence consistency where and when optical breakdown occurs. These factors need to be correctly managed in order to achieve optimum system performance. The Ultra Q photodisruptor system utilizes the most state-of-the-art technologies available today which include proprietary designs for laser cavity and power supply. Its innovative approach to laser beam generation, power management, system control and aiming beam technology results in the most precise optical breakdown at lowest energy levels. This makes the Ultra Q the ultimate photodisruptor for any quality-oriented ophthalmologist, and especially for cataract and refractive surgeons.

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## References

- 1 Alfred Vogel and Vasan Venugopalan "Mechanisms of Pulsed Laser Ablation of Biological Tissues" Chem.Rev.2003, 103, 577644
- 2 Vogel,A.; Busch,S.; Parlitz,U.J. Acoust.Soc.Am. 1996, 100, 148.
- 3 Steinert R, Puliafito CA. "The Nd:YAG Laser in Ophthalmology" Saunders.1985, 31-33
- 4 Encyclopedia of Physics and Technology. Paschotta. 2007.

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