AppNote3: KMLabs lasers are future-proof

(or, "How to protect your ultrafast investment")

Our Dragon and Wyvern ultrafast laser amplifiers are unique in the ultrafast marketplace in that they employ patented cryogenic cooling capability pioneered at KMLabs. Cryogenic cooling is a critical technology for these systems because, in cooling the laser crystal to ~50K, thermal lensing is virtually eliminated. This has several advantages that give our systems a significant edge in real-world usability:

1. KMLabs cryo-cooled lasers have **greater power handling** capability for Ti:Sapphire by up to 2 orders of magnitude.
2. KMLabs lasers can use a **wide variety of pump lasers**: frequency-doubled Nd:YLF, Nd:YAG, and pulsed or CW Nd:YVO4.
3. KMLabs ultrafast lasers can operate at **BOTH high repetition-rate AND high pulse energy**
4. KMLabs lasers have **repetition rates and pulse energies that can be varied** over a significant range while retaining excellent beam quality, stable divergence, and beam pointing.

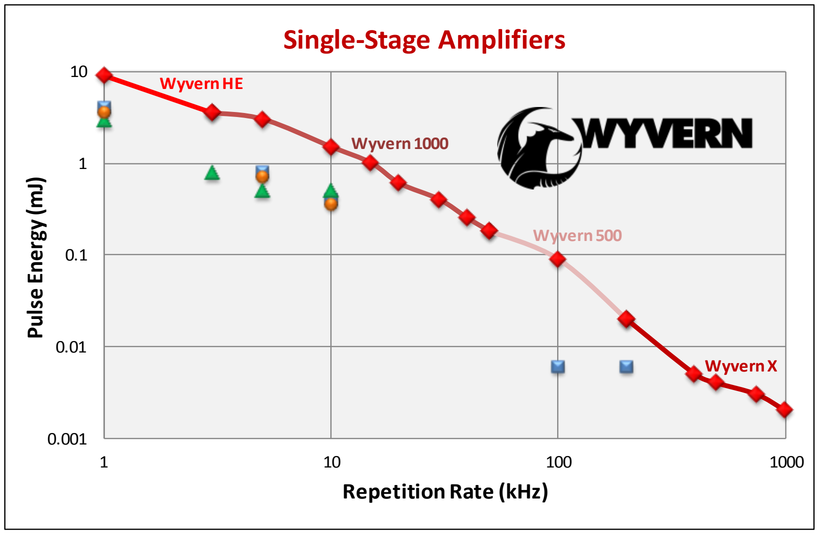
What does this mean in practice? First, KMLabs lasers offer a price/photon that is far lower than our competition. Our systems operate well over a *range* of repetition rates, in contrast to the typical *fixed* repetition rate used when a system is limited by thermal lens effects in Ti:Sapphire. The dramatic reduction in thermal distortion enables us to employ 532nm Nd:YAG pump lasers, which have an order of magnitude higher average power capability than an equivalent Nd:YLF laser, at a price point that is actually lower. A simple comparison:

- Diode-pumped frequency-doubled Nd:YAG 532nm pump laser in widespread use in industry for solar panel manufacturing: 100W power output, optimized in the 7-10 kHz range.
- Diode-pumped frequency-doubled Nd:YLF 527nm pump laser optimized for room-temperature Ti:Sapphire pumping: 20W power output @ 1 kHz. (= 5X lower power, at a comparable price!)

Using Nd:YAG pump lasers, the KMLabs Wyvern can generate an ultrafast laser output power of >15W, with potential for further increases as pump lasers with higher power become available. In comparison, the 1 kHz Nd:YLF-pumped single-stage system from our competitors give at most 3-5 W output power. This average power advantage is accentuated by the fact that the rep rate for the KMLabs laser is flexible. For example, the Wyvern 1000-15 amplifier pumped by a 100W Nd:YAG laser can operate over a range of repetition rates from 1-15 kHz, with a pulse energy in the 1-3 kHz range that is comparable to the competition. However, in real-world use most ultrafast laser applications require an optimized pulse energy, and cannot use an unlimited amount. In this situation *it is extremely advantageous to maintain the proper pulse energy and simply turn up the rep rate*. Applications that fit this scenario include high-order harmonic generation (HHG), micromachining and materials modification, and the pumping of Optical Parametric Amplifiers (OPAs) for mid-IR generation and spectroscopy. The application that KMLabs is most familiar with is coherent extreme ultraviolet (EUV) HHG. In HHG, focused light from the Ti:Sapphire laser ionizes a gas such as Argon, and EUV light is generated in the process. Physics dictates that the pulse energy must be enough to ionize the Argon, but past a critical ionization level the HHG emission saturates and additional pulse energy is not helpful. In the KMLabs

XUUS – our eXtreme Ultraviolet Ultrafast Source – this saturation occurs at pulse energies of ~0.5-1 mJ into the XUUS. For the HHG application, typically a user wants the highest possible *flux*. With the Wyvern-1000, they could generate suitable HHG light at repetition rates from 10-15 kHz, rather than only at 1 kHz.

Single stage ultrafast Ti:Sapphire amplifiers from KMLabs (line with red diamonds) and competitors' single-stage products (triangles, circles, squares). The Wyvern amplifiers from KMLabs offer higher powers in all cases, and also offer computer-controlled, variable repetition rates. All the competitive systems have fixed repetition rates. Multi-stage amplifiers from KMLabs (not shown here) also exceed the competitive multi-stage offerings.



Now…let's assume that this same Wyvern 1000 is transitioned for use in a different set of experiments. For example, in a future set of pump-probe experiments it may become necessary to pump a parametric amplifier with mJ-level energy. To generate the required 2 mJ output from a Wyvern 1000, the repetition rate can simply be adjusted to 7 kHz. If dual OPAs are necessary, the Wyvern 1000 can generate the necessary energies at 5 kHz. In this example, if a competitor's system is used instead of a KMLabs system, in the first experiment (HHG) only ~0.5 mJ of the available 3-4 mJ output can actually be used (0.5 W), and their rep rate cannot be increased. The result is more than an order of magnitude less average power, and implies that data acquisition which could be done in a day may take up to *2 weeks*. Furthermore, lower data rates always make optimization of an experiment more difficult.

It is important to emphasize that this scenario is quite common to nearly all productive ultrafast science labs. In the past, many people have agonized over whether to buy a 1 kHz ultrafast laser system or a 250 kHz system (the typical choices for products from our competitors). 250 kHz gives a much higher data rate, but the few microjoule pulse energy just *might not be enough* to make the experiment work. So the user purchases a 1 kHz system instead. Then they finds that they can only use ~10-20 µJ pulse energy, and ends-up with a very low data rate that makes a successful experiment very difficult. If this customer came to KMLabs, they would have a choice of laser systems that can generate >4 mJ @ 3 kHz, adjustable up to 15 kHz. Or, they could choose the Wyvern 500 laser, which operates at repetition rates of 50-200 kHz with pulse energy of 50-500 µJ – 1-2 orders of magnitude higher pulse energy than the competition's 100-250 kHz option.

KMLabs offers the most versatile, "future-proof" ultrafast amplifier systems, which can easily be adapted to a variety of experimental conditions.