Technical Information Bulletin

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Kerr Lens Modelocking

Coherent Internal Use Only

What is Kerr Lens Modelocking?

Enclosed is a set of figures which schematically explain the principles behind Kerr Lens Modelocking (KLM).

This effect is a new passive modelocking technique, developed by Coherent, which has not been used before. It is different from previous modelocking techniques in that it does not require an actively modelocked pump source, a flowing saturable absorber, or high frequency modulation to generate short pulses. Modelocking is based on the optical Kerr effect, which creates an intensity dependent lens in a crystal. This lens formation is the result of an intensity dependent index of refraction in titanium:sapphire crystals.

When the laser is modelocked, the peak power of each pulse will be very high, and will cause a significant change in the refractive index over the area of the beam as it travels through the Ti:S crystal. This creates an effective lens in the cavity, and will significantly change the divergence and waist of the beam as it travels through the cavity. Hence, the mode that exists in a modelocked cavity is very different from the mode that exists in a CW cavity.

It is possible to take advantage of this difference in modes by introducing more gain for the modelocked mode. By creating a more favorable condition (lower threshold) for modelocked operation, the laser will preferentially modelock. The effect can be made stronger with careful mirror design and cavity parameter selection. This is what we have done at Coherent.

The rest of the problem (dispersion compensation) is the same as that encountered in any femtosecond laser, such as the Satori. Prisms can be used to reduce the frequency chirp in the pulses as they travel around the cavity. All frequencies present in the pulse can now be effectively phase-locked together, and the output pulsewidth is nearly transform limited. This is how Coherent is able to obtain femtosecond pulses in the modelocked Ti:S, just as we did in the Satori™.

In the future, there will be an optional modification such that picosecond performance will also be possible. This option will be available some time after the introduction of the femtosecond version, but will be completely compatible with the original design. Upgrades/conversions between the two will be possible.

- **Overhead Explanations**

1) Summary of the way in which the Optical Kerr Effect produces (left) the modelocking effect through changes in the spatial profile of the beam and (right) how GVD compensation from the prisms balancing self-phase modulation (SPM) shortens and stabilizes the pulses (and thus enhances modelocking).

2) Schematic description of how the high peak power (modelocked) mode of operation sees more gain per pass, as a result of better overlap with the pumped gain profile, than the CW mode.

3) and 4) How the negative dispersion properties of prism pairs are used to balance the positive GVD and SPM in the cavity. This is the same principle as in the Satori except that the Ti:S crystal itself produces much more positive GVD and SPM than found in a dye laser. Also the four-prism construction is replaced by one double-passed prism pair.

5) An example of the effect of varying the amount of GVD compensation (by simply adjusting the amount of prism glass in the beam) on the pulsewidth, corresponding bandwidth and power in the laser. This shows how the pulsewidth can be adjusted while maintaining near-transform limited pulses. The peak power in the laser and the output power are determined by the output coupler design. The peak power level must be within a range whereby the KLM modelocking effect is maintained.

   This represents only a single unoptimized example of operation and is not to be considered best ever, typical, or a specification. Optimization of the cavity optics will determine the final product performance.

6) The product matrix for the modelocked Ti:S laser.

   The Ti:S laser will be initially released as a femtosecond laser. A picosecond version of the laser (or the addition of a picosecond option to the fs laser) will also be available in the near future. The recommended pump lasers will be either the small frame Innova® 310, or a large frame Innova 200 (both with powertrack). There will be low power (initially) and high power (later) options for the laser. Initial specifications will be announced at product release.

7) Comparison of Tsunami (2 ps with 1W output) with a Coherent laser (assuming 200 fs, 1W output)

This package should be helpful to those of you who have been requesting more information about the upcoming Modelocked Ti:S laser.

<u>Please do not</u> leave this information with customers, but feel free to show them the overheads when explaining the operation of the laser.

—Colin Seaton

Kerr Lens Modelocking

Optical Kerr Effect

Intensity dependent refractive index

- self-focussing
- spatial index variation

- Increased round-trip gain

  match spatial profile to excited gain volume

- Decreased round-trip loss

Self Phase Modulation

- expanded bandwidth

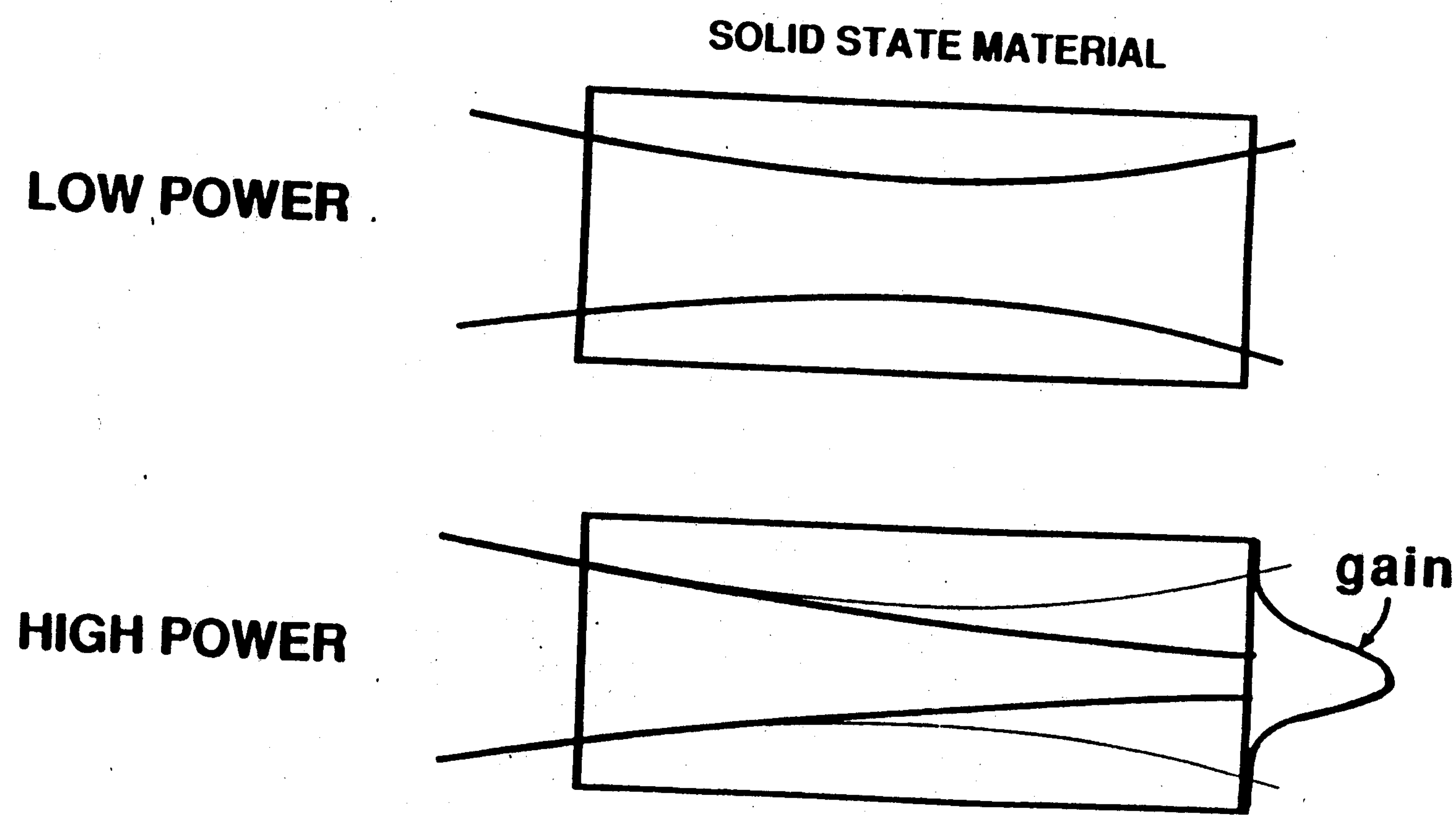
+ GVD compensation

- soliton-like pulse formation

STABLE, HIGH POWER, ~100 fsec MODELOCKED TI:S LASER

Coherent, Inc.

KERR LENS MODE LOCKING



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