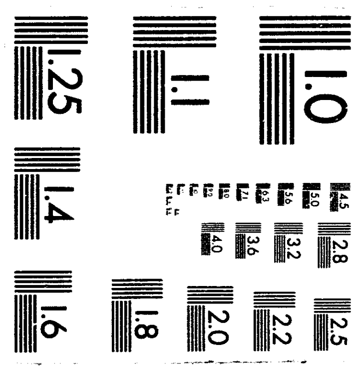
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Optical parametric Generation and Amplification of intense tunable femtosecond Pulses by a regeneratively-amplified Ti:Sapphire Laser.

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(708) 252-3541

The design for a optical parametric generator - optical parametric amplifier using KTP pumped by a regeneratively-amplified Ti:Sapphire laser is given. The frequency-doubled, microjoule-energy femtosecond pulses are tunable from 550 to 840 nm.

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There has been a recent serge in the development of optical parametric oscillators partially due improvements in crystals (e.g., LBO and BBO) and laser pump sources (Ti:Sapphire). There has been comparatively little work done on optical parametric generator-optical parametric amplifier (OPG-OPA) systems, which have the potential to provide the intense (microjoule) pulses that are necessary for many experiments. Those OPG-OPA systems that have been built are based on 10 Hz pump lasers. Several have been built that operate in the ps[1, 2] and fs[3-5] regimes. The advent of regeneratively-amplified Ti:Sapphire lasers[6] has provided a fs source with enough energy to pump an OPG-OPA at 1 kHz.

The choice of the nonlinear crystal depends on many factors, including the ability to phase-match over the desired tuning range, the size of the nonlinearity (d_{eff}), the group velocity mismatch (GVM) between the signal (or idler) and the pump, and the damage threshold. Given a near-IR fs pump, KTP is superior to both LBO and BBO. Type II phase-matching in KTP is used with an $o \Rightarrow e + o$ (pump $\Rightarrow$ signal + idler) polarization scheme. The beams propagate in the *xz* plane; i.e.,φ = 0°. Wavelength tuning is achieved by varying the angle θ between the pump wavevector and the *z*-axis of the crystal. The phase matching curves for KTP pumped at 840 and 775 nm are shown in Fig. 1. The Sellmeier coefficients of Kato[7] were used to satisfy the phase-matching condition $n_p\omega_p - n_s\omega_s - n_i\omega_i = 0$. Other Type II phase-matching schemes exist for KTP; however, none of the others have a wide tuning

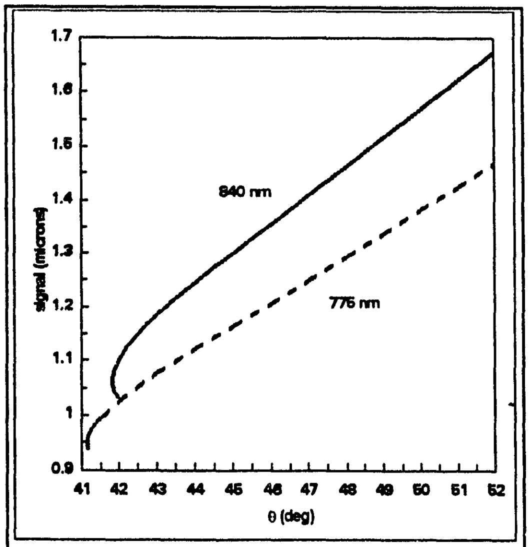

Fig. 1. Phase-matching curves for KTP (Type II, $o \Rightarrow e + o$) pumped at 775 and 840 nm.

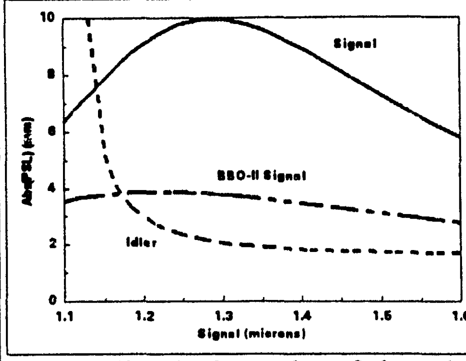

Fig. 2. The absolute value of the pulse-splitting lengths for the signal and idler in KTP pumped at 840 nm by 200 fs pulses. The PSL for the signal in Type II BBO is shown for comparison.

range with a near-IR pump wavelength.

Perhaps the most important factor in determining the optimal crystal for the OPG-OPA when using femtosecond pulses is the GVM, which is given by $1/v_j - 1/v_p$, where j refers to the signal or the idler. The GVM for the signal in KTP is ≈25 fs/mm with a 840 nm pump. A useful way of viewing the GVM is the pulse-splitting length[5], l, which is given by τ_p/GVM, where τ_p is the pulse-length of the pump. The pulse-splitting lengths for both the signal and the idler for KTP pumped at 840 nm are shown in Fig. 2. The pulse-splitting length (PSL) of the signal is positive in this wavelength range, while the idler's is negative. The signal PSL for BBO using Type II phasing (also pumped at 840 nm) is shown for comparison. The PSL for KTP pumped at 775 nm was also calculated. For this wavelength, the *minimum* PSL for the signal within the tuning range is 12 mm (GVM = 17 fs/mm), and at $\lambda_s = 1.25$ μm, the pump and the signal travel at the same group velocity.

The gain of the parametric process with perfect phase matching for the limit of high gain is

$$G_0 = 0.25\exp(2\Gamma_0 L) \tag{1}$$

where

$$\Gamma_0 = 2d_{eff}\sqrt{\frac{\omega_s\omega_i\Phi}{\varepsilon_0 n_s n_i n_p c^3}} \tag{2}$$

and L is the length of the crystal and Φ is the pump intensity. The effects of GVM and pump depletion are not included here. We define a modified figure of merit,

$$FOM_j = \frac{l_j d_{eff}}{\sqrt{n_s n_i n_p}}, \qquad j = s,\ i \tag{3}$$

that is useful for comparing the effectiveness of various crystals by taking into account the pulse-splitting length, which limits the effective interaction length of the crystal. A comparison of KTP and BBO pumped at 840 nm shows that the modified figure of merit

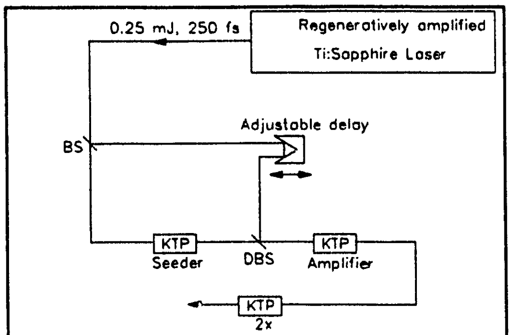

Fig. 3. OPG-OPA schematic layout. BS, beamsplitter; DBS, dichroic beamsplitter.

for the signal for KTP is better by at least a factor of three in the wavelength range of interest, corresponding to a factor of 20 greater gain.

The design for the OPG-OPA is shown in Fig. 3. The 250 μJ, 250 fs output of the regeneratively amplified Ti:Sapphire laser is beamsplit to provide a separate pump for both the seeder (OPG) and amplifier (OPA) stages. An adjustable delay for the pump of the amplifier crystal allows temporal overlap of that pump pulse with the signal generated in the first KTP crystal. The KTP crystals are 3x3x6 mm, cut at $\varphi = 0°$, $\theta = 46°$. Since the crystal length is below the PSL, little or no temporal broadening is anticipated. The output of the OPG-OPA is focused into a KTP doubling crystal to provide microjoules of energy from 550 nm to the wavelength of the pump.

We have designed a simple system to provide intense femtosecond pulses in the visible part of the spectrum using a regeneratively-amplified Ti:Sapphire laser as a pump source. This extends the operating wavelength range of fs solid state systems into a extremely important region of the spectrum that has been previously readily accessible only with dyes. This system should provide superior performance to kHz amplified dye laser systems.

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