주기적으로 분극반전된 $LiNbO_3$에서 군속도 일치와 의사위상정합에 의한 펨토초 펄스의 효율적인 2차 조화파발생

Effective frequency doubling of fs-pulse with simultaneous group velocity matching and quasi-phase matching in periodically poled lithium niobate

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Since group velocity (GV) mismatch significantly limits the efficiency of nonlinear interactions such as second harmonic generation (SHG), several techniques have been developed to compensate GV mismatch. The simplest way to avoid the GV mismatch problem is to reduce the device length. However, it results in a poor trade-off between the SHG spectral bandwidth and the conversion efficiency. Sophisticated methods have been proposed to cope with the narrow bandwidth problem. Domain-engineered quasi-phase matching (QPM) structures were used to achieve a better trade-off between the bandwidth and the conversion efficiency [1]. Martinez proposed a tilted pulse scheme that utilized the angular spectral dispersion of a diffraction grating or a prism for ultra-short pulse amplification [2]. Recently, we have demonstrated a simple type I (o+o→e) QPM scheme using d_{32} in a periodically poled MgO-doped lithium niobate crystal (PPMgLN) for the fundamental wavelength at 1560 nm [3]. With this method, we could obtain efficient broadband SHG without ripples in the pass-band.

Based on the same type I configuration, here we demonstrate 95 fs-pulse doubling with almost no temporal walk-off between the fundamental (FM) and the second harmonic (SH) pulses with 10-mm device length in PPMgLN. GV matching (GVM) and QPM were simultaneously achieved in a simple periodic structure. We performed temporal and spectral characterizations of the output SH pulses to visualize the effects of GVM. In Fig.1 we plotted the GV dispersions in 5 mol% MgO-doped lithium niobate at room temperature using the reported Sellmeiers formulas [4]. GVM is satisfied between the ordinary FM wave and the extra-ordinary SH wave around 1560 nm. It should be noted that it is possible to tailor material dispersion by choosing an appropriate dopant and the concentration, in order to achieve the desired GVM wavelength.

PPMgLN samples were fabricated by the electric poling technique with a QPM period of 20.1 m [5]. The FM source was an optical parametric amplifier (OPA) generating 95 fs pulses at 1 kHz repetition rate. The OPA beam was polarized along the crystalline y-axis and propagated along the *x*-direction for type I interaction utilizing d_{32}. A maximum SHG bandwidth of 25 nm was obtained at a sample temperature of 16.5 °C. For temporal characterization, we also performed intensity autocorrelation of the SH output using a BBO crystal. Fig. 2 shows the autocorrelation trace for type I interaction at an input peak intensity of 5.2 MW/cm^2. The SH pulse width was estimated 108 fs assuming a Gaussian pulse shape. For comparison, we also performed conventional type 0 (e+e →e, using d_{33}) QPM SHG with the same sample. The output SH spectrum was as narrow as 1.4 nm, implying that significant pulse broadening has occurred due to the GV mismatch. The autocorrelation trace of the type 0 SH output had triangular shape. The triangular shape indicates that the SH pulse has a rectangular shape resulting from the large temporal walk-off between the FW and the SH pulses. The FWHM of ~3000 fs agrees well with the group delay of 2860 fs calculated by the Sellmeiers formula at room temperature.

The present simultaneous GVM/QPM scheme can be useful not only for effective and distortion-free ultra-fast pulse doubling, but also for optical parametric generation, temporal soliton generation and pulse compression.

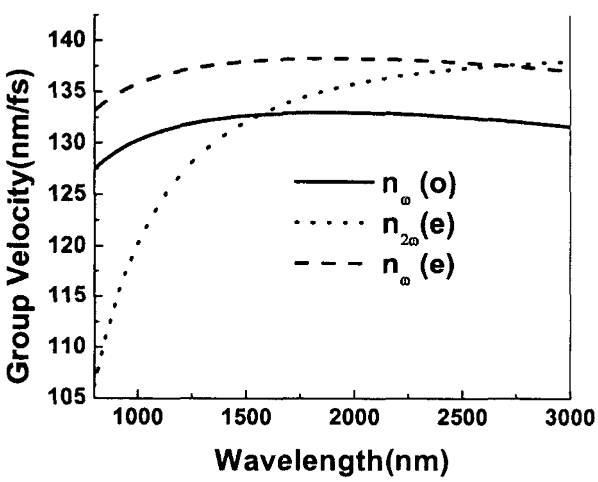

Fig. 1 Group dispersion of 5 mol% MgO-doped $LiNbO_3$ at room temperature

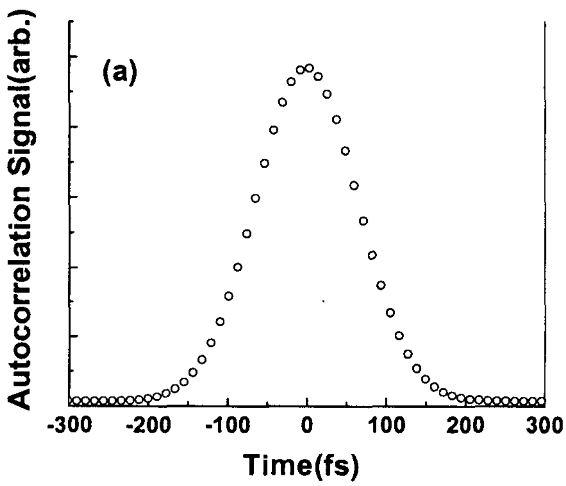

Fig. 2 Autocorrelation trace of second harmonic output pulse for type I interaction

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