Optical Society of Korea Annual Meeting 2002 (2.19~20, 2002)

전방진행축퇴사광파혼합 신호의 입사광 세기와 펄스모양에 대한 의존성

Input beam intensity and temporal pulse shape dependence of forward degenerate four-wave mixing

Dai-Hyuk Yu, Jai-Hyung Lee, Joon-Sung Chang, Jae-Seok Ryu*, Jae Won Hahn*, Paul M. Danehy**
School of Physics, Seoul National University
*Laser Metrology Group, Korea Research Institute of Standards and Science
**Instrumentation Systems Development Branch, NASA Langley Research Center
dhyou@photon.snu.ac.kr

A theory of FDFWM in homogeneously broadened two-level absorbers is presented for arbitrary-intensity input beams. An analytical solution of FDFWM is derived by assuming no pump beam depletion, strong pumps and weak probe. The shape of the analytical solution of FDFWM is different to that of PC-DFWM derived by Abrams and Lind[1], but it becomes equivalent to that of PC-DFWM in case of low absorption or large detuning. Also, the validity of applying the PC-DFWM theory to FDFWM experiments is discussed.

For arbitrary beam intensities and absorption parameters, signal intensity is obtained by numerically solving the coupled equation of complex amplitudes. The results of the numerical calculation and the analytical solution of FDFWM are compared for various probe to pump beam intensity ratio. Even when the probe beam is smaller than the pump beam by an order of two, there are notable differences between the numerical calculation and the analytical solution, owing to the probe beam saturation effects on the signal generation. The validity of using the analytical solution of FDFWM to the practical experimental conditions is also discussed. In Fig.1, the numerically calculated spectral lineshape is shown. In the strong absorption case, a dip appears on the top of the lineshape owing to two different mechanisms; absorption and saturation. Furthermore, the linewidth is also found to show two kinds of behavior. When the absorption is dominant, the linewidth grows smaller with the increase in the input intensity, but when the saturation is dominant, usual power broadening is restored.

The effects of laser pulse shape on forward degenerate four-wave mixing in two-level saturable absorbers have been demonstrated and discussed. First, the signal temporal shape is calculated assuming the coherence decay time is small compared to the pulse duration. By varying the ratio of pulse duration of the Gaussian input beam(τ) to the population relaxation time(T_1), the effects of the pulse temporal width to the FDFWM signal generation are shown and discussed. From this comparison, it is found that if τ/T_1 is larger than 10, then assuming steady-state gives fast and accurate results. Second, in the limit of $\tau \gg T_1, T_2$ the differences in signal behavior from the various pulse shapes are theoretically calculated and discussed. For all conditions, the signal intensity and the lineshape from the square pulse input shows stronger saturation than the other pulse shapes. The difference is enormous when the input beams have very high intensity. It is found that the existence and the distribution of the weak intensity part of the pulse has an important role in the signal intensity and lineshape, especially with the saturating input intensities. These results are explained to be caused by the different intensity distribution in the time domain. In the case of a Gaussian laser input, the weak intensity part of the pulse can generate signal effectively even for strong peak intensities. However, in case of a square pulse there is no such weak intensity part, so that the generated signal shows strong signal decrease with increasing intensity at very high intensities. The different relative portions of the weak and strong intensity parts for the Gaussian and Q-switched pulses also make differences in the signal intensities and lineshapes.

When the shape of input pulse is taken into account for the calculation of the FDFWM signal, the calculated lineshape is in very good agreement with the experimental data[2] as shown in Fig. 2.. This result shows the remarkable success of the simple theoretical extension of steady-state calculations to the pulsed laser experiments.

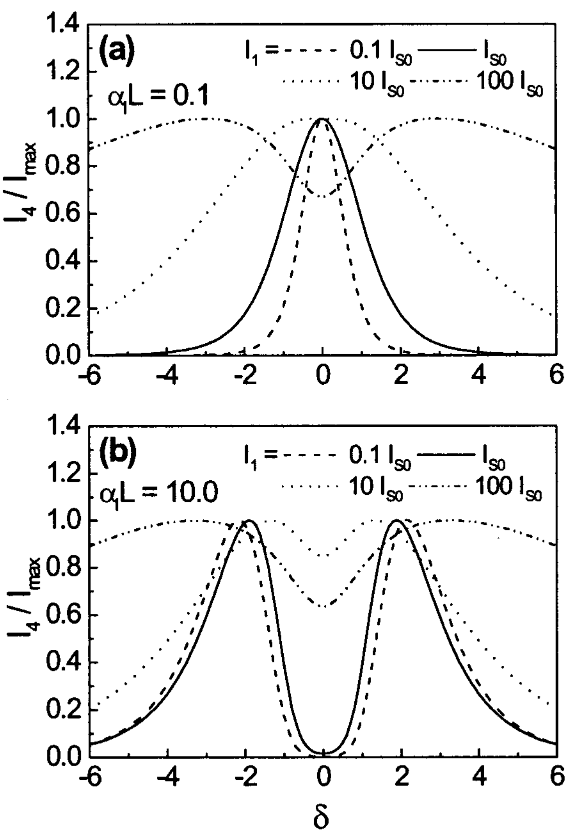

Fig. 1. FDFWM lineshapes for various pump beam intensities. $I_3 = 0.01 I_{so}$

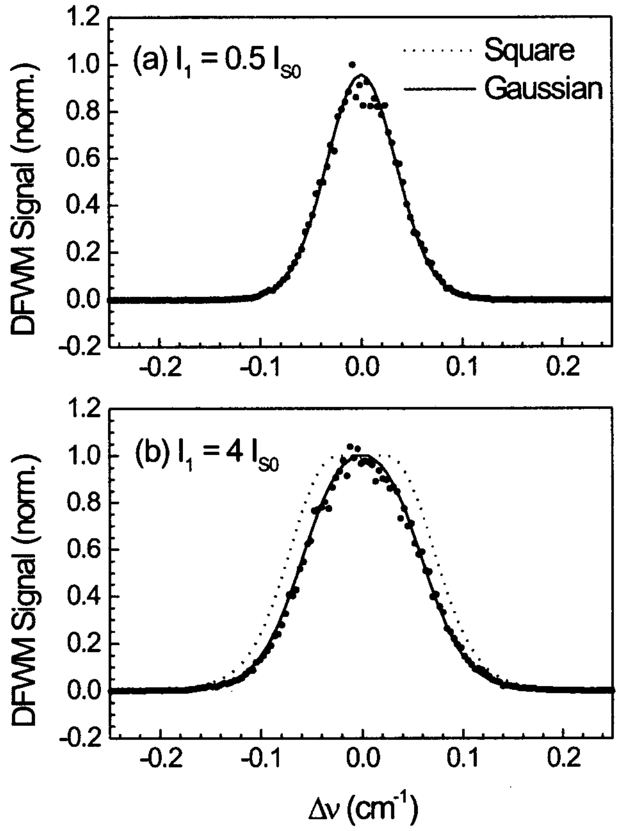

Fig. 2. Comparison between the experimental data[2] and two kinds of calculations with the two different shapes of pulse input for the $O_{12}(2)$ line of NO. The collisional width and Doppler width was $0.025 cm^{-1}$ and $0.1 cm^{-1}$, respectively.

1. See, for example, R. A. Fisher, ed., Optical Phase Conjugation (Academic, New York, 1983) and H. J. Eichler, P. Gunter, and D. W. Pohl, Laser-Induced Dynamic Gratings (Academic, New York, 1984).
2. T. A. Reichardt, R. P. Lucht, P. M. Danehy, and R. L. Farrow, "Theoretical investigation of the forward phase-matched geometry for degenerate four-wave mixing spectroscopy," J. Opt. Soc. Am. B, **15**, 2566-2572 (1998).