포화흡수 분광학의 해석적 이론
Analytic theory of the saturated absorption spectroscopy

Geol Moon, Heung-Ryoul Noh
Department of Physics and Institute of Opto-Electronic Science and Technology,
Chonnam National University, Gwangju 500-757, Korea
e-mail: hrnoh@chonnam.ac.kr

We present analytic theory of the saturated absorption spectra. By solving the rate equations in the presence of a pump laser beam, we obtained analytic forms of all the ground and excited-states populations, and calculated the absorption of a counterpropagating probe beam. We compared the analytic solutions with the numerical and experimental results and found good agreement between them. In addition, the results are compared with Nakayama's model. Compared to Nakayama's model, the analytic theory can provide accurate spectra at arbitrary intensity and diameter of the pump beam.

When we calculate the analytic spectra, we use the average time $t=(\sqrt{\pi}/2)d/u$, where d is the pump beam diameter and u is the most probable speed. In Fig. 1, we can see the good agreement with the experimental results. Although we did not include any other line broadening effects than the saturation, the numerical[(1)] and analytic results could predict almost correct spectra. The results from Nakayama's model can provide qualitatively similar results with the experimental, numerical, and analytic calculations. However, there exists some discrepancy between the Nakayama's and other results, in particular in Fig. 1(a). As well, Nakayama's model can not explain the broadening of the signals.

The dependence of the SAS spectra depending on the laser beam diameter or the intensity can be obtained from the analytic results, which can not be drawn from the Nakayama's model. In a previous paper[(2)], we reported on the study of the nonstationary effect in the SAS and compared the experimental results for the variation of the SAS spectra depending on the pump beam diameter with the numerical ones. Since the numerical and analytical results exhibit almost similar predicted spectra, we can much more conveniently compare the experimental results with theory by means of the analytic results.

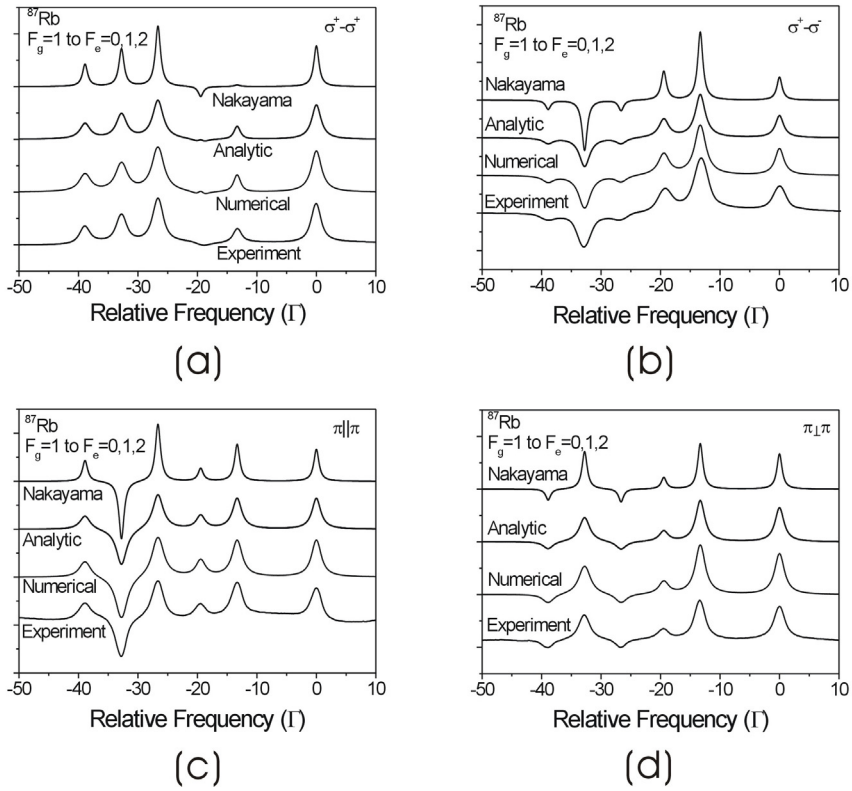

Fig 1. The experimental, numerical, analytic, and Nakayama's results for the SAS spectra at the transition $F_g=1 \rightarrow F_e=0,1,2$ when the pump-probe polarization configurations are $\sigma^+-\sigma^+$(a), $\sigma^+-\sigma^-$(b), $\pi||\pi$(c), and $\pi \perp \pi$(d).

1. G. Moon and H. R. Noh, J. Korean Phys. Soc. **50**, 1037 (2007)
2. G. Moon and H. R. Noh, Opt. Commun. 281. 294 (2008)