Vacuum-Ultraviolet Generation Using Electromagnetic-Field-Induced Transparency

Harris, Field, and Imamoğlu[1] (HFI) have demonstrated how the transparency induced by the electromagnetic field can be used to enhance the efficiency of nonlinear generation in the scheme shown in Fig. 1. They found that in the limit of very large Rabi frequencies compared to the Doppler width, the efficiency factor

$$\eta_{\mathrm{HFI}} \equiv |\chi^{(3)}(\omega_a,\omega_b,\omega_c)/\mathrm{Im}\chi^{(1)}(\omega_a+\omega_b+\omega_c)| \qquad (1)$$

is very large. In an earlier work[2] the present authors (TA) had also considered the changes in the absorption and dispersion characteristics of a medium due to an external electromagnetic field, and had shown how this can modify the characteristic of vacuum-ultraviolet (VUV) generation. In fact, it was predicted that VUV generation was possible in regions where it was normally forbidden and this was experimentally verified.[3] This level scheme is also shown in Fig. 1. The purpose of this Comment is to point out that the efficiency factor η_{TA} in this scheme is comparable to η_{HFI}, provided one uses the two-photon resonance which has been used in Ref. 1, and the Rabi frequency of the field used to create the transparency is much larger than the Doppler width. We have shown analytically that the ratio $\eta_{\mathrm{TA}}/\eta_{\mathrm{HFI}}$, in the limit of (a) large Rabi frequencies compared to the Doppler width, (b) all decay rates of the off-diagonal elements of the density matrix much smaller than the Doppler width, and (c) a resonant situation, is

$$\eta_{\mathrm{TA}}/\eta_{\mathrm{HFI}} = (\Gamma_2/\Gamma_4)[(\omega_a+\omega_b+\omega_c+\omega_l)/(\omega_a+\omega_b)]\,, \qquad (2)$$

where Γ_2 and Γ_4 are the two-photon and four-photon linewidths. Thus the efficiencies in the two schemes are comparable if the two linewidths, Γ_2 and Γ_4, are comparable. Note that if Γ_4 is negligibly small, then $\mathrm{Im}\chi^{(1)}$ and $\chi^{(3)}$ are small, requiring much larger cell lengths or pressures. The general result for arbitrary values of the linewidths and Rabi frequencies is shown in Fig. 1. It is clear from this figure that either scheme can be used for enhancing the efficiency of VUV generation.

Even for the homogeneously broadened case we find from the analytical results of Refs. 1 and 2 that $\eta_{\mathrm{TA}}/\eta_{\mathrm{HFI}}=1$, for large Rabi frequencies and for the on-resonance situation of the HFI and TA schemes shown in Fig. 1. The origin of the transparency in HFI (TA) is due to the smallness of the two- (four-) photon resonance linewidth. This leads to $\mathrm{Im}\chi^{(1)} \propto \Gamma_2$ (HFI) or Γ_4 (TA); $\chi^{(3)} \propto 1$ (HFI) or Γ_4/Γ_2 (TA). However, since the optimum generation of VUV is determined by the ratio $\chi^{(3)}/\mathrm{Im}\chi^{(1)}$, the efficiency factors in the two schemes are the same for the stated conditions of two-photon resonance and for nonzero four-photon linewidth Γ_4.

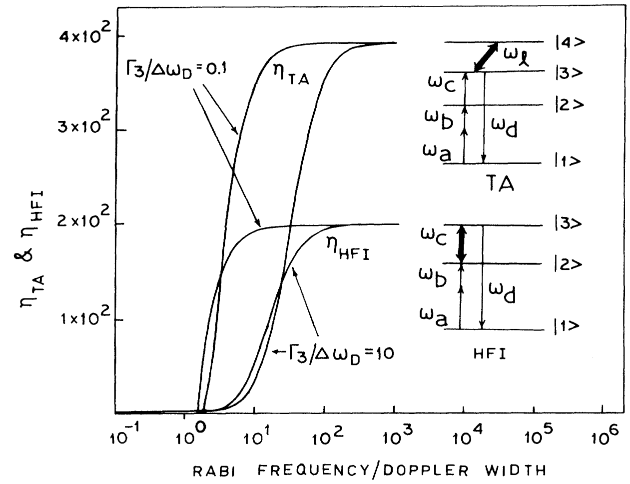

FIG. 1. Efficiency as a function of the Rabi frequency of the field used to create transparency for $\Gamma_2=\Gamma_4=0.01\Delta\omega_D$. All frequencies are in units of the Doppler width $\Delta\omega_D$ of the VUV transition. Inset: The two level schemes; Γ_3 is the homogeneous linewidth of the VUV transition.

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