Hiệu ứng trong suốt cảm ứng điện từ (EIT- Electromagnetically Induced Transparency) là kết quả của giao thoa lượng tử giữa các dịch chuyển trong nguyên tử (phân tử) dưới sự kích thích kết hợp của các chùm laser. Do sự giao thoa này, môi trường sẽ trở nên trong suốt đối với một chùm sáng (thường gọi là chùm dò) dưới sự điều khiển của một chùm sáng khác (được gọi là chùm liên kết).

http://thuvien24.com/hieu-ung-trong-suot-cam-ung-dien-tu-cua-he-nguyen-tu-rb85-ba-muc-nang-luong-99099.html

Dispersive properties of electromagnetically induced transparency An atomic transition that has been made transparent by applying an additional electromagnetic field exhibits a rapidly varying refractive index with zero group velocity dispersion at line center. A 10- cm-long Pb vapor cell at an atom density of 7xl015 atoms/cm3 and probed on its 283-nm resonance transition has a calculated optical delay of 83 ns KC/VG) “250].	Tính chất tán sắc của vật liệu trong suốt cảm ứng điện từ 12 h 47 Khi áp một trường điện từ vào môi trường vật chất, quá trình dịch chuyển điện tử tạo ra hiện tượng trong suốt, quá trình dịch chuyển này dẫn đến sự thay đổi chiết suất nhanh cùng với hiện tượng tán sắc vận tốc nhóm bằng không tại line center (trung tâm vạch, ngay giữa vạch). Thí nghiệm được tiến hành trên một cuvet chứa hơi Pb dài 10 cm ở mật độ 7×10^{15} nguyên tử/cm^3, chúng ta tiến hành dò dịch chuyển cộng hưởng 283 nm của nó, thời gian trì hoãn quang học theo ước lượng khoảng 83 ns $[(\frac{c}{V_G} = 250)]$.
It has recently been demonstrated that an optically thick transition may be made nearly transparent to light at its resonance frequency [1,2]. This is done by applying an electromagnetic field (Fig. 1) which dresses the upper state of the transition and thereby creates a quantum interference at a probe wavelength. The applied electromagnetic field may be another laser or a microwave or dc field. The transition may be broadened by autoionization, radiative decay, and, in certain cases, by collision. In this Rapid Communication (một dạng bài báo ngắn, trình bày những công trình có ý nghĩa khoa học cao) we calculate the dispersive properties of such a media. The real and imaginary parts of the susceptibility as functions of the probe frequency are shown in Fig. 2. Because of the absorptive interference and the symmetry of the	

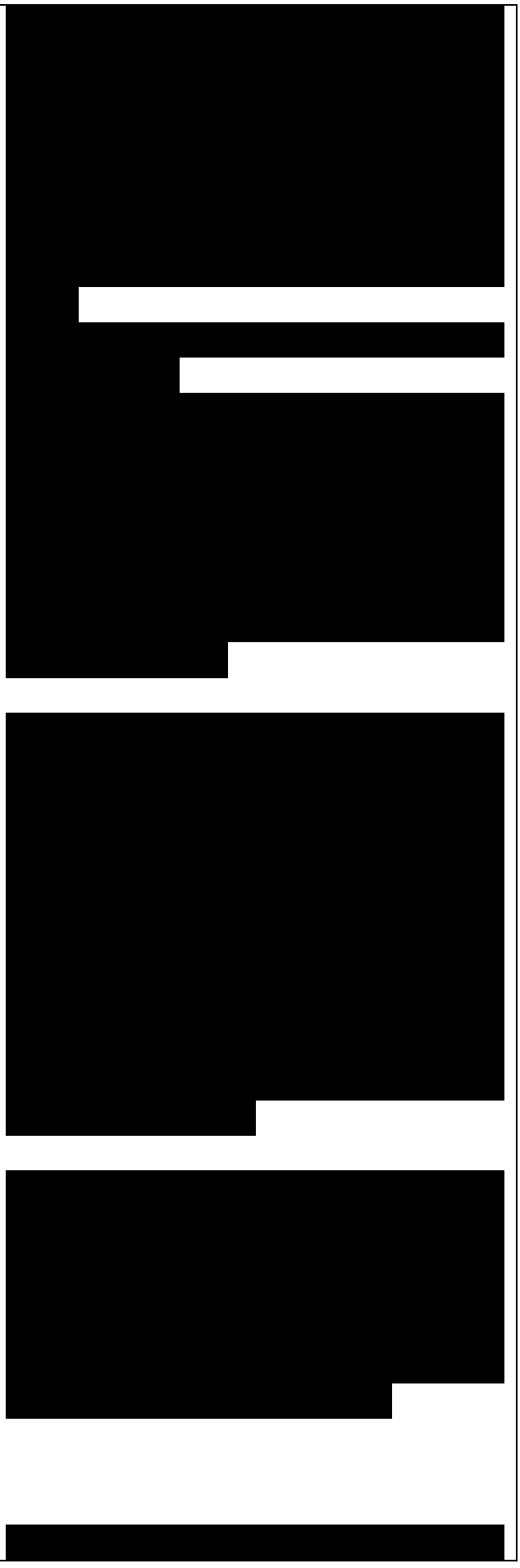
dressed states, the probe, when tuned to the position of bare state |3), experiences a linear rapidly varying refractive index with very slow group velocity and zero group-velocity dispersion. This slow group velocity is the result of the slope and not of the magnitude of the refractive index, which remains nearly unity.

FIG. I. Energy-level diagram for the transparency process. When a strong field of frequency <OC is tuned to line center of the |2>—► 13) transition, where state |2> is metastable, the medium becomes transparent to a field of frequency EO tuned to line center of the |l>—1► |3) transition.

Tewari and Agarwal [3] and Harris, Field, and Imamo- glu [4] have noted that the dispersive properties of a mac-roscopic medium may be modified by a strong (dressing) electromagnetic field. In related work, Scully [5] has noted the possibility of using coherence to allow an increased refractive index. The basic phenomenon which creates this transparency is termed as population trapping and has been studied extensively [6-9].

We work with the probe envelope quantities E(T) and PIT) with Fourier transforms E(A) and P{(O). We take the probe to have a center frequency COO, expand the susceptibility of the dressed atom to third order about this value, and Fourier transform. With P(O> — AO) = EOX(<*> — O)O)E((O — MO)

FIG. 2. (a) Imaginary and (b) real parts of the susceptibility of a probe



frequency O> in the presence of a strong-coupling field O)C- The dotted curve of (a) is the imaginary part of the susceptibility in the absence of the coupling field. Normalization is to the peak value of the imaginary part of the susceptibility.

For this work we take ©o equal to the frequency of the bare 11 >—► 13> transition. The values of the real and imaginary parts of the dressed susceptibility x an(^ the pertinent derivatives evaluated at this frequency are given in Table I. The quantity to is the permittivity of free space. The quantity is the Rabi frequency of the resonantly driven |2>—► |3> transition; i.e., Clc "*iinEclh. The formulas, as written here, are for a lifetime-broadened system with decay rates of states \l) and |3> of I"2 and IY

When pressure broadening is important then, to within the accuracy of the impact approximation, T2 and r3 may be replaced by r2+2yi2 and T-$+2yn, respectively; the quantities 2712 and 2/n are full width at half maximum collisional Lorentzian widths. The formulas of Table I and, therefore, the results of this paper, are dependent on the assumption that the Rabi frequency of the probe is small as compared to that of the coupling laser.

The equation for the slowly varying envelope E(z,t) is then

f+(a+,p)£+if,3,

where

a — — ^ lmx((t)0)

A,

The quantities A and P are the per length E field loss and phase shift at t»o, VQ is the group velocity, and 62 and 63 determine the pulse distortion and therefore the ability to resolve the delayed pulse.

In the (hypothetical) ideal case where state |2> is completely metastable (r2“0) and the probe is tuned to (OQ, there is complete interference and perfect transparency for all nonzero

both P and the group-velocity dispersion (the real part of BI) are zero. For finite r2 the transparency results from both the interference and the separation of the dressed states. At small the interference dominates and the pulse distortion is the result of the nonzero loss (62) of off-line-center Fourier components. At sufficiently large CIC the medium is transparent over the pulse bandwidth and the distortion comes from the curvature of the real part of the susceptibility 63.

For a medium of length L the time delay relative to a pulse traveling at velocity C is L{(\/VG) — (l/c)]. For a sufficiently monochromatic pulse, we take the maximum usable L as l/2a. For fl|»r2r3 (Table I), the time delay TO in one attenuation length (power) is

i.e., the maximum time delay for a pulse which propagates one attenuation length is equal to the decay time of meta-stable state |2>.

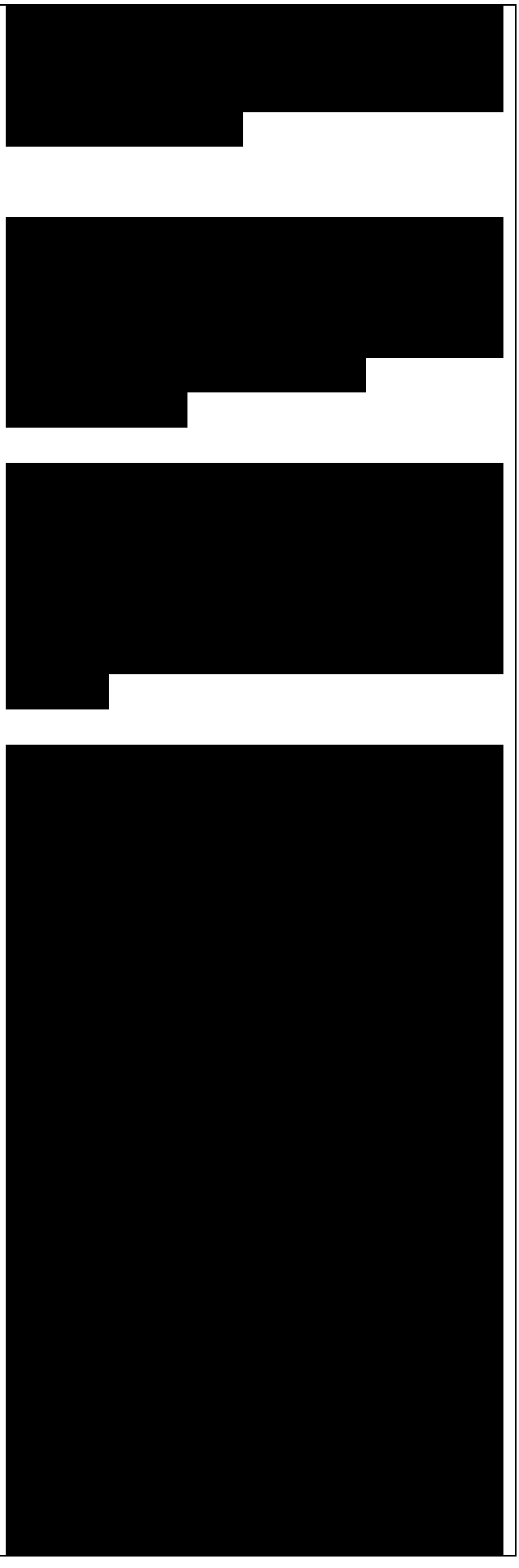
For an exponential pulse with a characteristic rise or fall time r, we take XM\„ as that time constant which pro-duces a distortion of

magnitude 1/a. Assuming either 62 or 63 dominates, then rmin is the larger of

We define a parameter q as the ratio of the total delay to rmjn. This parameter is a measure of the resolvability of the delayed pulse and for the limits of Eqs. (5a) and (5b), respectively, is

TABLE I. Susceptibilities and derivatives. All quantities are to be multiplied by lnu^N/eoh. To include collision broadening, T2 and r3 should be replaced by T2+2/12 and T3+2/I3, respectively; 2712 and 2713 are full width at half maximum Lorentzian collisional widths.

One may compare the dispersive properties of the dressed atom with the probe tuned to COO with those of the same atom with =0 and the probe tuned off of line center by Ao so as to equalize the attenuation at the same pressure and cell length. This detuning is Ato-rOV-M^) l/2]nc. Proceeding as above, the total time delay of the bare atom in a single attenuation length is 1/r3; rmin“(2/r3AG)) ^2; <72“(Aco/2r3),/2; and the ratio of the group velocities of the bare to dressed atom is r3/r2. Because the group velocity dispersion of the dressed atom is zero at too, it has a much greater pulse resolvability than does a bare atom. (Instead, one may assume a hypothetical bare atom with a transition oscillator strength such that r2“r3 and assume that both the atom density and the detuning are increased to make the loss length, the group velocity, and the pulse



resolvability Q the same. One finds that to do so the ratio of the atom densities of the bare-to-dressed atom must be 4Q2, which, for reasonable pulse resolution, is impractical.)

Though this Rapid Communication is concerned with the linear response, we note that for r2=0 and CO “coo, *(3)(— CO,A), — (D,<D) —0, as do all similar terms of higher order. Nonlinear susceptibilities such as %I3)(— (O,AC,. — (OC,(O) are included within this formulation and, for these same conditions, are also zero.

We observe that there is an unusual type of spatial pulse compression inherent to these formulas. As a pulse enters a medium with a very slow group velocity and (approximately) unity refractive constant, its peak electric field and power density are unchanged and the pulse compresses spatially by a factor of C/VG. The energy density is primarily determined by the slope rather than the magnitude of the susceptibility [10] and the power density (E$C/2)\E\2 equals the product of the energy density and group velocity.

The previous formulas have ignored inhomogeneous broadening. For the medium to be transparent we therefore require that the Rabi frequency of the |2>—*■ |3) transition be sufficiently large that the transmission hole width [(r2/r3)l/2]nc. is large as compared to the two-photon Doppler width of the 11>—► |2> transition. (In the usual sense of Doppler-free, two-photon processes, this width depends

on the direction of propagation as well as the frequencies of the two beams; for a system where state |2) is above state |3> and the beams counterpropagate, it approaches zero as the frequencies approach each other.)

We proceed with an example: We assume a 10-cm-long 208Pb vapor cell at an atom density of 7x 1015 atoms/cm . The probe transition is 6SZ6P23PO—>► 6S26PLS 3P\ with a wavelength of 283 nm and an oscillator strength [11] of GF “0.197. The coupling laser transition is 6j26/j23P2 —► 6S26P7S 3P1 with X“405.9 nm and GF =‘0.11. For an atom density of 7x1015 atoms/cm , the quantities T3+2yi3 and r2+2yi2 which replace r3 and r2 in the formulas are 4.46xl08 sec-1 and 1.20xl07 sec-1 [12,13], respectively. It is implicitly assumed that the linewidth of the coupling laser is narrow compared to this last value [14]. We choose the Rabi frequency of the |2)—► 3> transition so that the power attenuation of the probe beam is unity; i.e., l/2a”10.0 cm. This Rabi frequency is sufficiently large that the two-photon Doppler width s^O.Ol cm-1 is unimportant. This requires an CLC of about 0.7 cm-1, which occurs at a coupling laser power density of 283 kW/cm2. For these conditions c/Vg ”250, the total time delay is 83.3 ns, and the resolvability <73—248. These quantities may be compared to those of the transition without the coupling laser present. With CLc”0 and the probe laser detuned by Ato”2.14 cm-1 so as to again obtain a 10.0-cm power absorption depth, we find

c/Vg “6.73, a total time delay of 2.24 ns, and a ratio of total delay to minimum pulse length of ^2”21.3. (These single transition results are in the spirit of those observed by Grischkowsky [15].)

From Eq. (5) we see that, for large Rabi frequency, the minimum pulse length which one may use to observe these slow group velocities is GVnf)2/3(2/r2). For reasonable coupling laser power the minimum pulse length in metal vapors is a few tenths of a nanosecond. The slow group velocities described here are also, in essence, a bandwidth limitation on the use of electromagnetically induced transparency to obtain large nonlinear coefficient length products for nonlinear sum and difference frequency generation [3,4,16], For the output power of the generated signal to grow as the cell length squared, the generated pulse must be sufficiently long that it does not temporarily slip from the driving pulse in the cell or opacity length.

A device of this type may someday provide what might be termed as a group-velocity optic. For polarization in the same plane, the group velocity depends on the relative angle of the polarization of the coupling field and probe lasers and therefore varies with probe propagation angle. At the same time, the phase delay is invariant to propagation angle.