Effects of mismatched transmissions on two-mode squeezing and EPR correlations with a slow light medium

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We theoretically discuss the preservation of squeezing and continuous variable entanglement of two mode squeezed light when the two modes are subjected to unequal transmission. One of the modes is transmitted through a slow light medium while the other is sent through an optical fiber of unit transmission. Balanced homodyne detection is used to check the presence of squeezing. It is found that loss of squeezing occurs when the mismatch in the transmission of the two modes is greater than 40% while near ideal squeezing is preserved when the transmissions are equal. We also discuss the effect of this loss on continuous variable entanglement using strong and weak EPR criteria and possible applications for this experimental scheme.

I. INTRODUCTION

The phenomenon of Electromagnetically Induced Transparency (EIT) has been the focus of intensive research in the last decade. The experiments performed so far using EIT have led to an extensive understanding of the transmission of light pulses and preservation of classical coherence features such as pulse shape. With the emergence of the field of quantum computing, the ability to use EIT to hold and transmit quantum coherence (and hence quantum information) is a possible tool for creating future quantum computational devices.

Squeezing of interferometric noise below the standard quantum limit is an important quantum coherence phenomenon. Further two-mode squeezing has been widely used to study continuous variable entanglement. A recent experiment 1 examines the preservation of squeezing when squeezed vacuum light is transmitted through an EIT medium. In that experiment both modes of a two-mode squeezed light were transmitted through an EIT medium and two mode squeezing was maintained in the transmitted light over the entire transparency window bandwidth. Another recent work 2 theoretically examines the preservation of single mode squeezing and entanglement from an EIT system. In this paper we theoretically examine the preservation of continuous variable entanglement and squeezing when one of the modes of a two-mode squeezed light is transmitted through an EIT medium while the other mode is propagated through an optical fiber delay line. The light transmitted through the EIT medium and the delay line is then be mixed together and balanced homodyne measurements made to check for squeezing. This experiment leads to a better understanding of the effects of the EIT medium on the fluctuations, and hence coherence properties, of quantum light. We find that differences in transmission of the two modes leads to loss of entanglement and squeezing. We discuss the possible causes for this loss and the effect of mismatched transmission on the entanglement and EPR correlations 3 in an ideal two-mode squeezed state. Possible applications of this experimental scheme to continuous variable teleportation and cryptographic schemes are also discussed.

II. EXPERIMENTAL SETUP

Figure 1 is the schematic experimental set-up. An Optical Parametric Amplifier (OPA) pumped by a laser is the source of squeezed light. The OPA uses a Type-II degenerate downconversion to generate squeezed vacuum light in two orthogonally polarized modes with the same frequency. The center frequency of the OPA is matched with the center frequency of the probe transition of the EIT medium. The two modes from the OPA are separated using a polarizing beam splitter (PBS) and one of the modes is input into the EIT cell while the other is sent through a delay line. The output from the EIT and the delay line are mixed together at another polarizing beam splitter. This light is then mixed with a local oscillator of the same frequency at a 50-50 beam splitter (BS) and reaches the detectors $D_1$.
II. EXPERIMENTAL SETUP TO CHECK PRESERVATION OF SQUEEZING IN EIT MEDIUM

FIG. 1: Experimental set-up to check preservation of squeezing in EIT medium

and $D_2$. The power spectrum of the difference current from the two detectors gives the measure of the noise in the quadrature measured. The control field of the EIT is external to the setup and is assumed to be stable.

III. THEORETICAL ANALYSIS

In this section we provide a theoretical analysis of the experiment. We give a brief description of the OPA and the EIT medium before entering into the complete calculation.

A. Input-Output equations for OPA

The treatment of the OPA follows that in [4]. We assume a cavity OPA with no input in the squeezed modes and an undepleted pump. The operator relations of the input and output fields of the OPA are as follows. The quantized electric field at the output of the OPA is given by

$$E^{(+)}_{\text{out}}(t) = \sqrt{\hbar \omega_0 / (4 \pi \varepsilon_0 c A)} (d^{\text{out}}_o(t) \mathbf{i} + d^{\text{out}}_e(t) \mathbf{j})$$

(1)

where $\mathbf{i}$ and $\mathbf{j}$ are unit orthogonal vectors indicating the polarization of the field. Note that we use continuum field quantization for fields outside the OPA [5]. $A$ is the cross-sectional area determined by the geometry of the experiment, $\omega_0$ is the center frequency of the OPA, $d^{\text{out}}_o(t)$ and $d^{\text{out}}_e(t)$ are the annihilation operators for the ordinary and extraordinary polarized photons at the output of the OPA in a frame rotating with frequency $\omega_0$:

$$d^{\text{out}}_{o,e}(t) = \frac{1}{\sqrt{2\pi}} \int d\omega D^{\text{out}}_{o,e}(\omega) e^{-i(\omega_0 - \omega)t}.$$  

(2)

The integral in Eq. (2) is over the bandwidth of the OPA. The relation between the input and output operators of the OPA are given by

$$D^{\text{out}}_{o,e}(\omega) = G(\omega) D^{\text{in}}_{o,e}(\omega) + g(\omega) D^{\text{in} \dagger}_{o,e}(-\omega)$$

$$D^{\text{out} \dagger}_{o,e}(-\omega) = G(\omega) D^{\text{in} \dagger}_{o,e}(-\omega) + g(\omega) D^{\text{in}}_{o,e}(\omega)$$

(3)

where

$$G(\omega) = [\kappa^2 + (\gamma/2 + i\omega)(\gamma/2 - i\omega)]/M$$

$$= G^*(-\omega)$$

$$g(\omega) = \kappa \gamma / M$$

$$= g^*(-\omega)$$

$$M = (\gamma/2 - i\omega)^2 - \kappa^2$$

(4)
\( \gamma \) is the damping rate of the OPA, assumed to be the same for both the modes, and \( \kappa \) is the coupling coefficient including the pump field of the OPA. For an amplifier \( \kappa < \gamma / 2 \). The bandwidth of the OPA is assumed to be \( \gamma \). Note that in this description of the OPA we have assumed that there are no other external losses except through one port which serves as both input and output port of the OPA.

### B. Parameters of EIT medium

\[ \chi(\Omega) = \frac{N|\mu_{ac}|^2}{\hbar \epsilon_0} \frac{\Omega - i \gamma_b}{(\Omega - i \gamma_b)(\Omega - i \gamma_c) - \Omega_c^2} \]  

where \( N \) is the density of the atoms in the EIT medium, \( \mu_{ac} \) is the dipole matrix element of the probe transition, \( \Omega_c \) is the Rabi frequency of the control field, \( \gamma_b \) and \( \gamma_c \) are the decay rates of the states \(|b\rangle \) and \(|c\rangle \) respectively.

The complex factor picked up by the probe field as it traverses the medium is given by

\[ T(\omega_p) = e^{i k_{EIT}(\omega_p)z} = e^{i(k_{EIT}(\omega_{ca})-\Omega \frac{d k_{EIT}}{d\omega}|_{\omega=ca}+\Omega^2 \frac{d^2 k_{EIT}}{d\omega^2}|_{\omega=ca})z} \]  

where \( z \) is the length of the EIT medium. We have made an assumption that the detuning from resonance \( \Omega \ll \omega_{ca} \) so that the wave vector \( k_{EIT} \) can be expanded about the resonance. Using

\[ k_{EIT}(\omega) = \frac{\omega}{c} \sqrt{1 + \chi(\omega)} \]  

and assuming that \(|\chi(\omega)| \ll 1\), we get,

\[ T(\Omega) = e^{\chi_1(\Omega\omega_{ca})} e^{\chi_2(\Omega\omega_{ca})} \]  

where \( \chi_1 \) and \( \chi_2 \) are the real and imaginary parts of the susceptibility.

### C. Calculation

We now proceed to calculate the noise in the measured quadrature of light transmitted through the EIT and the delay line. We use a circularly polarized classical local oscillator field,

\[ E_{LO}(t) = |\beta_{LO}|(e^{-i(\Omega_{LO}t-\phi_{LO})} + e^{i(\Omega_{LO}t-\phi_{LO})})(i + j) \]
where $|\beta_{LO}|$ is the classical amplitude, $\Omega_{LO}$ the frequency and $\phi_{LO}$ the tunable phase of the local oscillator field. In the following calculation, we assume that the central frequency of the OPA ($\omega_o$), the central frequency of the probe transition ($\omega_{ca}$) and the local oscillator frequency ($\Omega_{LO}$) are identical.

$$\omega_o \equiv \omega_{ca} \equiv \Omega_{LO}$$  \hspace{1cm} (10)

The field at the detectors $D_1$ and $D_2$ are given by

\begin{align*}
E_1^{(+)}(t) & = \frac{i}{\sqrt{2}} \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} (id_A(t)i + d_B(t)j) + \frac{1}{\sqrt{2}} |\beta_{LO}| e^{-i(\Omega_{LO} t - \phi_{LO})} (i + j) \\
E_2^{(+)}(t) & = \frac{1}{\sqrt{2}} \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} (id_A(t)i + d_B(t)j) + \frac{i}{\sqrt{2}} |\beta_{LO}| e^{-i(\Omega_{LO} t - \phi_{LO})} (i + j)
\end{align*}

(11)  \hspace{1cm} (12)

$d_A(t)$ and $d_B(t)$ are photon annihilation operators at the output of the EIT and the delay line respectively. Homodyne detection involves studying the noise in the difference current from the two detectors $\bar{R}$. The difference current is given by

$$I_D(t) = E_2^{(-)}(t) \cdot E_2^{(+)}(t) - E_1^{(-)}(t) \cdot E_1^{(+)}(t)$$

(13)

$$I_D(t) = i \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} |\beta_{LO}| \left[ e^{-i(\Omega_{LO} t - \phi_{LO})} (id_A^t(t) + d_B^t(t)) - e^{i(\Omega_{LO} t - \phi_{LO})} (id_A(t) + d_B(t)) \right]$$

(14)

Since $\Omega_{LO} = \omega_o$, we use the transformation,

$$d_A(t)e^{i\Omega_{LO} t} = D_A(t)$$

(15)

$I_D(t)$ can be re-written as

$$I_D(t) = i \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} |\beta_{LO}| \left[ e^{i\phi_{LO}} (-iD_A^t(t) + D_B^t(t)) - e^{-i\phi_{LO}} (iD_A(t) + D_B(t)) \right]$$

(16)

We now Fourier transform Eq. (15), since we are interested in the spectrum of squeezing.

$$I_D(\Omega) = i \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} |\beta_{LO}| \left[ e^{i\phi_{LO}} (-iD_A^t(\Omega) + D_B^t(\Omega)) - e^{-i\phi_{LO}} (iD_A(\Omega) + D_B(\Omega)) \right]$$

(17)

The operators $D_A(\Omega)$ and $D_B(\Omega)$ are now expressed in terms of operators at the output of the OPA.

$$D_A(\Omega) = T(\Omega) D_o^{\text{out}}(\Omega) + i R(\Omega) D_v(\Omega)$$

(18)

$$D_B(\Omega) = i e^{i k_f(\Omega) x_f} D_e^{\text{out}}(\Omega) = i e^{i \left( \frac{x_f}{V_f} \right) \cdot \overrightarrow{k_f} L_f} D_e^{\text{out}}(\Omega) = i e^{i \phi_d(\Omega)} D_e^{\text{out}}(\Omega)$$

(19)

We have used a beam splitter to model the loss due to the EIT medium $\bar{R}$. Note that the amplitude transmittance and reflectance, $T(\Omega)$ and $R(\Omega)$, are complex quantities. $D_v(\Omega)$ is the amplituditation operator of an uncorrelated vacuum mode entering into the system, $n_f(\omega_o)$ is the refractive index of the fiber at the central frequency of the light, $V_f$ is the group velocity of the light in the fiber and $l_f$ is the length of the fiber. We assume a lossless fiber and ignore the dispersion in the fiber. The light through the EIT is filtered by the transparency window and the light transmitted through the delay line picks up a phase $\phi_d(\Omega)$ where $l_f$ is chosen such that the fields at the output of the EIT and the fiber arrive in phase. Eq. (17) is rewritten as

$$I_D(\Omega) = \sqrt{\frac{\hbar \omega_o}{4 \pi \epsilon_0 c A}} |\beta_{LO}| \left[ e^{i\phi_{LO}} (T^*(\Omega) D_o^{\text{out}}(\Omega) - i R^*(\Omega) D_v^t(\Omega)) \right.$$

$$+ e^{-i\phi_{LO}} (D_e^{\text{out}}(\Omega)) + e^{-i\phi_{LO}} (T(\Omega) D_o^{\text{out}}(\Omega) + i R(\Omega) D_v(\Omega) + e^{i\phi_d(\Omega)} D_e^{\text{out}}(\Omega)) \right]$$

$$= 2 \sqrt{\frac{\hbar \omega_o}{\pi \epsilon_0 c A}} |\beta_{LO}| X^{\phi_{LO}}(\Omega)$$

(20)  \hspace{1cm} (21)

The quadrature being measured, $X^{\phi_{LO}}(\Omega)$, is defined in Eq. (21).
We can use Eqs. (3) to relate the output operators to the vacuum input of the OPA. The presence of squeezing is checked by measuring the noise level of the quadrature and comparing with standard quantum level, in this case, 0.5. The result of this calculation is found to be

\[
(\Delta X^{\phi_{LO}}(\Omega))^2 = \frac{1}{4} |R(\Omega)|^2 + |G(\Omega)|^2(1 + |T(\Omega)|^2) + |g(\Omega)|^2(1 + |T(-\Omega)|^2) + 2|T(\Omega)|Re[g(\Omega)G^*(\Omega)e^{i(\phi_1(\Omega)-2\phi_{LO}+\frac{\omega_0z}{c})}] + 2|T(-\Omega)|Re[g(\Omega)G^*(\Omega)e^{i(\phi_1(\Omega)-2\phi_{LO}+\frac{\omega_0z}{c})}]
\]

We make the approximations \(|T(-\Omega)| = |T(\Omega)|\) since \(\chi_2(-\Omega) = \chi_2(\Omega)\) and \(\chi_1(-\Omega) = -\chi_1(\Omega)\). These approximations are valid only within the region of transparency and when the control field is resonant to the atomic transition \(|b\rightarrow c\). Using \(|R(\Omega)|^2 + |T(\Omega)|^2 = 1\), we have

\[
(\Delta X^{\phi_{LO}}(\Omega))^2 = \frac{1}{4} |(1 - |T(\Omega)|^2) + |G(\Omega)|^2 + |g(\Omega)|^2(1 + |T(\Omega)|^2) + 4|T(\Omega)||g(\Omega)G^*(\Omega) \times \cos\left(\frac{\Omega}{V_f}l_f + \frac{\chi_1(\Omega)\omega_0z}{2c}\right)\cos\left(2\phi_{LO} - \frac{\omega_0z}{c} - \frac{n_f(\omega_0)\omega_0}{c}l_f\right)\]

This is the final expression for the noise in the phase quadrature measured. The cosine terms in the above equation determine the phase quadrature being measured. The second cosine term varies only with the local oscillator phase \(\phi_{LO}\) since \(\omega_0z = n_f(\omega_0)\omega_0l_f\), the first order phase picked up due to the EIT and the delay line, is a constant for the experiment. The first cosine term depends on phase terms that are first order in the detuning \(\Omega\), for the values of EIT medium parameters used in this calculation, and the fiber. \(\frac{\omega_0z}{c}\) is the delay due to the EIT medium and, \(\frac{\omega_0z}{c}\) is the compensating delay introduced by the fiber. Note that though the phase quadrature \(X^{\phi_{LO}}\) is also determined by the Rabi frequency of the control field through \(\chi_1(\Omega)\), the squeezed quadrature remains unaffected as long as the fluctuations in the control field amplitude are not large.

The following were the values of OPA parameters used in the calculation whose results are illustrated in Fig.3:

The damping rate of the OPA is modeled as the leakage due to the input-output coupling mirror and given by \(\gamma = ct/2L\) where \(t\) is the transmittance of the mirror, and \(L\) is the length of the OPA cavity. \(\gamma\) is also a rough estimate of the bandwidth of squeezed light from the OPA. The values of the above parameters are chosen such that the bandwidth of the OPA is about 40 MHz, much larger then the transparency window. \(\kappa\), the coupling coefficient is chosen to be below the threshold of an oscillator, \(\kappa = (0.6)\gamma/2\).

The EIT medium is Rubidium(Rb) vapor and the probe resonance is the \(D_1\) line of Rb at 795 nm. The other EIT and optical fiber parameters have the following values:

\(|\Omega_i| = 20\text{MHz}, N = 2.7 \times 10^{17} \text{ atoms/m}^3, z = 0.05\text{m}, \gamma_b = 10^4\text{Hz}, \gamma_c = 6\pi \times 10^6\text{Hz and } |\mu_{ac}| = 1.46 \times 10^{-29}\). We assumed \(n_f = 1.5\) for frequencies around the probe resonance and \(V_f = 10^8\text{m/s}\) for the group velocity of light in the fiber. This gives us the length of the fiber \(l_f = 3.04\text{ km}\). The transparency window is approximately 1.2 MHz for the given control field strength.

**IV. RESULTS AND DISCUSSION**

In order to clearly understand the effects of mismatched transmissions on quantum coherence it is useful to compare with the case of equal transmissions of both modes of light.

By inspection of Eq. (23), the expression for the quadrature variance for identical transmission of the two modes is given by,

\[
(\Delta X^{\phi_{LO}}(\Omega))^2 = \frac{1}{2}[(1 - |T(\Omega)|^2) + |G(\Omega)|^2|T(\Omega)|^2 + 2|T(\Omega)|^2g(\Omega)G^*(\Omega) \times \cos\left(\frac{\Omega}{V_f}l_f + \frac{\chi_1(\Omega)\omega_0z}{2c}\right)\cos\left(2\phi_{LO} - \frac{\omega_0z}{c} - \frac{n_f(\omega_0)\omega_0}{c}l_f\right)\]

In Fig.3(a) and (b), we plot the quadrature variance derived in Eqs. (23) and (24) and \(|T(\Omega)|\) as a function of detuning. When the transmissions are mismatched squeezing is maintained over a bandwidth less than the transparency window. For matched transmissions, near ideal squeezing is maintained even beyond the transparency bandwidth defined by the \(|T(\Omega)| = 0.5\) line. In [1], the two modes in that experiment have different frequencies. Squeezing is
FIG. 3: $(\Delta X)^2$ (red) and $|T(\Omega)|$ (black) as a function of detuning $\Omega$ ($\phi_{LO}=2.4$). The dashed line $|T(\Omega)| = 0.5$ defines the bandwidth of the transparency window and the standard quantum noise limit $(\Delta X)^2 = 0.5$. Squeezing is indicated when the quadrature noise falls below the dashed line. In (a), the transmissions of the modes are not equal and the squeezing bandwidth is less than the transparency bandwidth. In (b), the transmissions are equal and near ideal squeezing is preserved.

Preserved over the entire transparency bandwidth but not beyond. We believe that this is because of nearly equal complex transmissions of the two modes. The difference in phase, picked up in the EIT medium by the two modes with slightly different frequencies, spoils the two-mode squeezing beyond the transparency bandwidth.

Quadrature phase amplitude measurements of two mode squeezed light have often been used to study continuous variable entanglement [4, 8]. The experiment discussed in this paper can be used to study the effect of EIT transmission on two mode squeezing and entanglement simultaneously although for a rigorous test of entanglement, the two modes may be detected separately and correlation measurements made on the photocurrents. Before we discuss these criteria, we need to rewrite the measured quadrature as follows.

$$X_\theta(\Omega) = \frac{1}{2} [(e^{i\theta}a^\dagger(-\Omega) + e^{-i\theta}a(\Omega)) - (e^{i\phi}b^\dagger(-\Omega) + e^{-i\phi}b(\Omega))]$$

$$= X_a - X_b.$$  

where

$$a(\Omega) = T(\Omega)D^\text{out}_\phi(\Omega) + iR(\Omega)D_v(\Omega), \quad b(\Omega) = e^{i\frac{\Omega}{\gamma_f}f}D^\text{out}_e(\Omega)$$

$$\phi = \pi + \phi_{LO} - \frac{n_f(\omega_0)\omega_0}{c}t_f, \quad \theta = \phi_{LO}.$$  

$$X_{\theta-\pi/2}(\Omega),$$ the quadrature involving the non-commuting observables of $X_a$ and $X_b$ can be written as

$$X_{\theta+\pi/2}(\Omega) = \frac{i}{2} [(e^{i\theta}a^\dagger(-\Omega) - e^{-i\theta}a(\Omega)) + (e^{i\phi}b^\dagger(-\Omega) - e^{-i\phi}b(\Omega))]$$

$$= P_a + P_b$$

Reid has suggested two EPR criteria - strong and weak - based on phase amplitude measurements to detect entanglement and EPR correlations in systems that are not maximally entangled [9]. These measurements are pertinent when an EIT medium is used since even perfectly entangled states are bound to be degraded by passage through the EIT medium as long as transmission is not unity. The stronger criterion given by,

$$\Delta(X_a - X_b)\Delta(P_a + P_b) < \frac{1}{4},$$

is in the spirit of the original EPR paradox [3] where local realism is defined with no assumptions regarding the form of a local realistic theory.

The weaker criterion, which is also a two-mode squeezing criterion, is given by,

$$\Delta(X_a - X_b)\Delta(P_a + P_b) < \frac{1}{2}.$$
This weaker criterion is based on the inseparability of an entangled state. The entanglement criteria suggested by Simon [10] and Duan [11] also belong to the weaker type.

FIG. 4: \((\Delta X)^2\) as a function of transmission at \(\Omega = 50\) KHz and \(\phi_{LO} = 2.4\). In (a) transmission of the two modes are unequal and squeezing is maintained only for \(|T| > 0.5\). In (b) both modes have equal transmission and all the transmitted light is squeezed. In both cases as the transmission increases first the weaker and then the stronger EPR criteria are satisfied.

Fig 4(a) shows the variance in one of the quadratures, \(\Delta(X_a - X_b)^2\), as a function of transmission through the EIT medium for a particular detuning. From the expressions for the phases \(\theta\) and \(\phi\) and the error in one of the quadratures given by Eq. (23), we see that the expression for quadrature noise does not change from \(X_\theta(\Omega)\) to \(X_{\theta + \pi/2}(\Omega)\). So both the quadratures, \(X_a - X_b\) and \(P_a + P_b\), are squeezed for a particular detuning \(\Omega\) and obey the weaker entanglement criterion in Eq. (31) when the mismatch between the transmissions is less than 40%. With further increase in transmission, the stronger criterion is also satisfied.

In Fig 4(b), where the transmissions are equal, all the transmitted light is squeezed and entangled either weakly or strongly. The squeezing is almost ideal. However, the strong EPR criteria is not satisfied till transmission is about 0.75 though the light from the OPA is ideally squeezed and obeys both the EPR criteria over the entire bandwidth \(\gamma\).

We find that the differences in transmission of the two modes adversely affect both entanglement and squeezing. This can be explained as follows. Squeezing occurs due to destructive interference of phase sensitive and insensitive fluctuations. As long as the transmissions of the two modes is not equal, the magnitude of destructive interference is not enough for the light to be squeezed. The low correlation of fluctuations also causes the loss of entanglement.

Loss of light through absorption or filtering is a common occurrence in any real world optical experiment. Up until now, the aim has been to avoid such losses in case of squeezing experiments since they lead to reduced squeezing efficiency by adding vacuum fluctuations. In this calculation we see that for two-mode squeezed light, squeezing can be preserved as long as the transmissions of the two modes are matched, even if they are less than unity. By coupling one mode into a fiber and varying it’s transmission, we can maintain two-mode squeezing in a small range of detuning within the transparency window while destroying squeezing coherence for all other detuning frequencies. Here we have used an EIT medium since it provides a smooth well understood transmission feature over a compact frequency bandwidth.

Teleportation and cryptography schemes using continuous variable entanglement in squeezed states have long been discussed in literature [12, 13]. The ability to selectively preserve entanglement and squeezing can be very useful in such schemes. The experiment suggested here provides a practical method to do this. For example, if the two modes are shared between two parties, the sequence of fiber transmissions, required to reconstruct the information contained in the entanglement, could be the shared key. In the absence of the key the information cannot be reliably reconstructed. Further any eavesdropping, by diverting part of a transmitted mode, adds vacuum noise that is easily detectable if the message cannot be reconstructed with the shared key. The EIT medium, apart from providing a varying transmission also slows down the transmitted light. The effects discussed here may also be important for application of any slow light effects in such continuous variable teleportation or cryptographic schemes.
V. SUMMARY

In this paper we have theoretically investigated the preservation of two mode squeezing and entanglement when the transmission of the two modes are not equal. An EIT medium provides varying transmission for one the modes and a fiber is used to transmit the other mode. We find that two mode squeezing is preserved as the transmission of both modes approach the same value. Using the strong and weak continuous variable entanglement criteria, we find that entanglement in the weak regime is maintained whenever two mode squeezing is preserved but loss of transmission degrades entanglement in the strong regime. We have also outlined a scheme by which two mode squeezing and entanglement can be selectively maintained or destroyed using varying fiber transmissions. Such a scheme, if experimentally demonstrated, can have interesting application to continuous variable quantum cryptography.

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