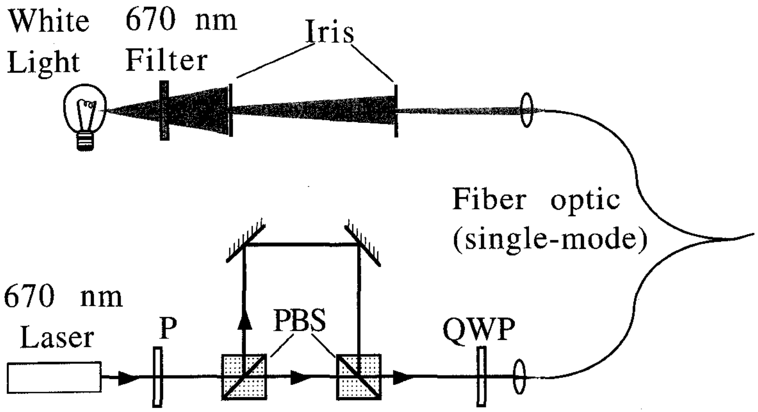
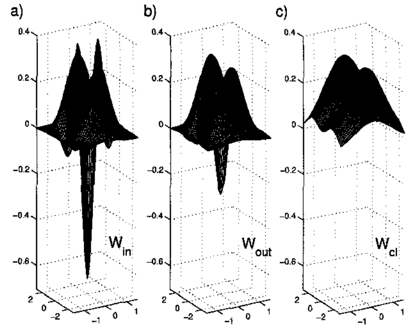


QWH1 **Fig. 2.** Two methods to prepare nonpure quantum states. The simplest, a filtered white-light source, produces a completely unpolarized state. The laser-diode version allows one to make an arbitrary quantum state by varying the input polarization to the polarizing Mach-Zehnder interferometer (which is unbalanced much more than the coherence length of the laser).



QH2 **Fig. 2.** (a) Wigner function $W_{in}(\alpha)$ for the input state $|\psi> \propto |+\alpha>+e^{i\phi}|-\alpha>$, with $\alpha = 1.5i$. (b) Teleported output state $W_{out}(\alpha)$ for squeezing parameter $r = 1.15$ and efficiency $\eta^2 = 0.99$. (c) Output state $W^{cl}_{out}(\alpha)$ for classical teleportation with W_{EPR} replaced by the vacuum state.

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QWH2 **2:45 pm**

Teleportation of continuous quantum variables

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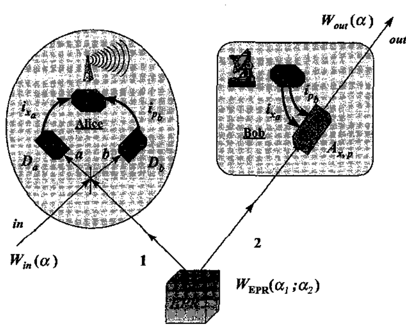
A particularly startling discovery by Bennett *et al.*[1] is the possibility for teleportation of a quantum state, whereby an unknown state of a spin-$\frac{1}{2}$ particle is transported by 'Alice' from a sending station to 'Bob' at a receiving terminal by conveying 2 bits of classical information.[1] Beyond the context of dichotomic variables, Vaidman has analyzed teleportation of the wave function of a one-dimensional particle in a beautiful variation of the original EPR paradox.[2] In this case, the nonlocal resource shared by Alice and Bob is the EPR state with perfect correlations in both position and momentum. Here we extend Vaidman's analysis to incorporate finite (nonsingular) degrees of correlation among the relevant particles and to include inefficiencies in the measurement process. We quantify the "quality" of the resulting protocol for teleportation with the first explicit computation of the fidelity of entanglement for a process acting on an infinite dimensional Hilbert space.[3] Finally, we report on our experimental progress towards quantum teleportation of continuous quantum variables, where now the entangled state shared by Alice and Bob is a highly squeezed two-mode state of the electromagnetic field, with the quadrature amplitudes of the field playing the roles of position and momentum as in Ou *et al.*[4] Note that up until now, all experimental proposals for teleportation have involved dichotomic variables.

As shown schematically in Fig. 1, an unknown input state described by the Wigner function $W_{in}(\alpha)$ is to be teleported to a remote station, with the teleported (output) state denoted by $W_{out}(\alpha)$. Alice (at the sending station) and Bob (at the receiving terminal) have previously arranged to share an entangled state, which is sent along paths 1 and 2, described by the Wigner function $W_{EPR}(\alpha_1,\alpha_2)$. The classical results (i_{x_a}, i_{p_b}) of linear measurements performed by Alice are sent to Bob and allow him to construct the teleported state $W_{out}(\alpha_2)$ from component 2 of the EPR state. Note that our analysis includes finite efficiencies in detection and propagation, as well as the finite degree of correlation of the state $W_{EPR}(\alpha_1,\alpha_2)$.[3]

To illustrate the protocol, we consider teleportation of the coherent superposition state $|\psi\rangle \propto |+\alpha\rangle + e^{i\phi}|-\alpha\rangle$, with corresponding Wigner function $W_{in}(\alpha)$ illustrated in Fig. 2a. The teleported Wigner function $W_{out}(\alpha)$ is shown in Fig. 2b for parameters corresponding to -10dB of squeezing with overall detection efficiency $\eta^2 = 0.99$, which should be compared with the parameters of Ref. 6 (namely -6 dB of squeezing and detectors with efficiency $\eta^2 = 0.99 \pm 0.02$). The quantum character of the state survives teleportation, including negative values for W_{out} associated with quantum interference for the off-diagonal components of ρ_{in}. For comparison, note that for classical teleporation, W^{cl}_{out} consists of the incoherent superposition of two distributions centered at $\pm\alpha$, as shown in Fig. 2c.



QWH2 **Fig. 1.** Illustration of setup for quantum teleporation of an unknown quantum state $W_{in}(\alpha)$ from Alice's sending station S to Bob's receiving terminal R, resulting in the teleported output state $W_{out}(\alpha)$.

We are currently working to realize a laboratory implementation of our teleportation scheme based upon extensions of Ref. 4 and 6. The progress of this endeavor will be described.

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QWH3 **3:00 pm**

Which-way information in an atom interferometer

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Duality is often used to highlight the difference between quantum mechanics and classical physics. It expresses the fact, that observation of interference and which-way information are mutually exclusive. It has been vividly discussed[1,2] recently, whether or not the loss of interference in an arbitrary which-way experiment can always be attributed to mechanical forces. While a lot of Gedanken experiments have been proposed, there are only a few experimental results. We now report on an experiment that addresses precisely this question.[3]

Our atom interferometer is based on Bragg scattering from standing light waves. A first standing light wave splits the incoming beam