one left-handed photon) $\otimes |l\rangle \rightarrow$

two left-handed photons) $\otimes |l+1\rangle$

Now suppose we take as our 'ready' state of the amplifier the state

$$|A_0\rangle \propto \sum_{l=-\infty}^{\infty} e^{-\alpha l^2} |l\rangle$$

Then it is a simple matter to show that for small α , the final state of the amplifier is practically independent of the polarization of the incoming photon, even though angular momentum is conserved. Indeed, the inner product between the two possible pure final states of the amplifier is $\exp(-2\alpha)$, which can be made arbitrarily close to unity. Thus, if angular momentum conservation were the only constraint, then the second situation we consider (that is, cloning with the final state independent of polarization) could in principle still be achieved to an arbitrarily good approximation. This is why it was necessary to give the argument based on the linearity of quantum mechanics, which clearly rules out this sort of cloning. Furthermore, the argument we gave can be generalized to apply to other quantum systems, for which angular momentum conservation may not be a relevant factor.

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Morphology of iodine-doped polyacetylene

THE extensive current interest in polyacetylene, $(CH)_x$, has been stimulated by the discovery that doping with donors or acceptors results in up to 12 orders of magnitude increase in the conductivity and the formation of the metallic state¹. Many aspects of this system remain controversial, including the mechanism for doping and the insulator-metal transition¹, charge transport¹, magnetic phenomena¹ and the fundamental crystal structure¹⁻⁴. The material synthesized utilizing the Shirakawa catalyst is fibrillar as grown, with 200-500 Å diameter fibrils⁵. The fibrillar morphology of this polymer has a central role in doping and compensation. The presence of these fibrils is important for rapid electro-

chemical doping and for potential battery applications⁶. Other morphologies have been suggested to result from polymerization in other conditions¹.

The detailed evolution of the fibrillar morphology with doping is very important for understanding the chemistry of doping and its reversibility as well as mechanisms for charge transport in the polymer. It was recently reported⁷ that the fibrillar morphology changes on doping with iodine^{7,8}. Initial doping was stated to result in the formation of aggregates followed by a uniform melt of various globular features at high doping levels. Contradictory observations that only swelling of the polyacetylene fibrils occurs on iodine doping were reported by another group^{9,10}. (In the studies of refs 9 and 10, 60:40 Au: Pd was used to overcoat the films examined.)

To resolve these differences, we have examined the role of surface versus cross-sectional morphology, the effects of tearing on the apparent cross-sectional morphology, as well as the effects of contrast in scanning electron microscope (SEM) photographs and the ramifications of the choice of coating deposited on the sample to reduce the charging effects. We were able to create the reported SEM patterns at will, and we conclude that the fibrillar morphology only swells on iodine doping, with no gross change in morphology.

Both the surface and cross-section of the film were observed to have the same fibrillar morphology, although sometimes dense matting would obscure the fibrils on the surface. Similarly, it was found that tearing would sometimes lead to drawing together of the fibrils into the featureless bundles reported previously⁷. Use of very high contrast highlights these features, making it even more difficult to observe the actual fibrillar morphology.

The choice of overcoating was observed to lead to very large effects. Without overcoating, the fibrillar morphology of the surface and bulk were clearly observed for $(CH_{1.08})_x$ and $(CH_{1.15})_x$, although sample charging did lead to some distortion of the image. D.C. plasma deposition (100 µm air present) of 80-100 Å of a 60:40 gold:palladium alloy (a composition often used in SEM studies^{11,12}) resulted in a sharper image with no charging. Use of 80-100 Å of evaporated or sputtered gold alone as the overcoating led, however, to an apparent aggregation of the gold on the surface. The resulting films no longer showed their fibrillar morphology. Instead clumps and aggregates were observed. Indeed, under high contrast bright white spots appear and all signs of the underlying fibrils (both surface and cross-section) are suppressed.

Our experiments have therefore enabled us to categorize the effects of surface versus bulk study, sample tearing, SEM contrast and metal deposition¹³. We have determined that the fibrillar structure is maintained with iodine doping although there is fibrillar swelling. There

is no evidence from these studies to support a percolation model of the insulator-metal transition. Sample tearing, high SEM contrast and gold deposition can lead to the observation of extrinsic nonfibrillar morphologies unrelated to the true polyacetylene morphology. Hence, care must be taken in the interpretation of any SEM data. All relevant conditions for the SEM studies must be known in order to interpret the micrographs properly.

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ROLLAND AND CADENE REPLY—Following Epstein *et al.*'s discussion of the morphology of iodine-doped $(CH)_x$, we would like to make some comments based on results of new experiments that we have carried out.