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1992 January 14



Dr. Herschel S. Pilloff
Office of Naval Research
Physics Division (Code 1112LO)
800 North Quincy Street
Arlington, Virginia 22217-5000

Dear Hersch,

This letter reports progress under ONR Grant No. N00014-91-J-1167 (R&T No. 4124112-05) during the period 1990 December 1 to 1991 November 30.

During this period four people were associated with me at USC. Alistair *Lane* continued as a postdoc through 1991 February 28; he returned to USC on a part-time basis as of January 1, his goal being to complete work initiated earlier. Rüdiger *Schack* joined my group on 1991 November 1 as a post-doctoral Visiting Scientist; *Schack*, who completed his Ph.D. last year under Axel Schenzle in München, is supported entirely by a German fellowship. Two USC graduate students, Chang *Zhu* and Shang *Song*, continued work toward Ph.D. degrees in Physics; *Zhu* should finish by May of this year and *Song* by the end of the calendar year.

Research during this period was concentrated in the following areas:

- *Caves* and Peter Drummond (University of Queensland) revised extensively their long paper on quantum limitations to communications rates and submitted it as a review paper to *Reviews of Modern Physics* (publication 4). The paper presents the first general proof of the wideband limit on channel capacity, and it develops the theme that when the energy in a channel is used most efficiently, there should be about one photon in each field mode, carrying about one bit of information. The paper has been reviewed once, and the authors have been urged to resubmit it with modifications. A shorter version of the paper will appear in the proceedings of the Cortina ARW on Quantum Measurements in Optics (publication 3).

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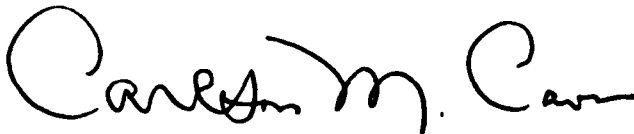
- *Song* and *Caves* initiated a detailed investigation of quantum limitations on high-precision interferometry. At present their analysis includes a realistic model of losses, quantum feedback to maintain the interferometer at its operating point, and the use of squeezed light. Still to be included are light recycling and imperfections leading to mode mismatching. This investigation will serve as *Song's* Ph.D. thesis.

- *Lane*, Samuel Braunstein (now at Technion Haifa), and *Caves* finished their investigation of Shapiro-Shepard-Wong (SSW) phase measurements. After considerable fluctuation, they finally concluded the following: within and somewhat outside the parameter range explored by their numerical simulations, SSW measurements come close to, but do not beat the standard $1/N$ limit on phase sensitivity. This contradicts the original claims made by SSW. On the other hand, it is not possible to reach firm conclusions outside the explored parameter range, as had been hoped, because of the possibility of certain subtle logarithmic corrections. A paper describing these and other results on phase measurements has been written, but awaits one further revision (by *Lane*) to make it consistent with these final conclusions.

- *Caves* and Gerard Milburn (University of Queensland) continued at a very low level of activity their investigation of reversible optical computers.

During this period *Caves* was an invited speaker at the Workshop on Squeezed States and Uncertainty Relations, held at the University of Maryland during 1991 March 28-30; he reported preliminary results on the investigation of SSW phase measurements. In addition, *Caves* attended the Santa Fe Workshop on the Foundations of Quantum Mechanics, held during 1991 May 27-31. Drummond attended the NATO Advanced Research Workshop on Quantum Measurements in Optics, held in Cortina, Italy, during 1991 January 21-25, where he reported on his and *Caves's* work on communication rates. Braunstein attended the Quantum Electronics and Laser Science meeting, held in Baltimore during 1991 May 13-17, where he reported on phase-measurement work and earlier work on the positive P representation, both carried out with ONR support.

Sincerely,



Carlton M. Caves

CMC/TeX

Publications published

1. S. L. Braunstein, C. M. Caves, and G. J. Milburn, "Interpretation for a positive P representation," *Physical Review A* **43**, 1153-1159 (1991).
2. C. M. Caves, C. Zhu, G. J. Milburn, and W. Schleich, "Photon statistics of two-mode squeezed states and interference in four-dimensional phase space," *Physical Review A* **43**, 3854-3861 (1991).

Publications submitted

3. P. D. Drummond and C. M. Caves, "Wideband quantum communication: A new frontier?" in *Quantum Measurements in Optics*, edited by P. Tombesi (Plenum, New York, to be published).
4. C. M. Caves and P. D. Drummond, "Quantum limits on communication rates," submitted to *Reviews of Modern Physics*.



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Statement A per telecon
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