seen by the slightly differently detuned meter beam. This change causes the phase of the meter beam to track the signal beam intensity. Measuring the phase with the help of a homodyne detection system determines the signal beam intensity with excellent fidelity. Signal beam losses were 10%, no perceptible noise was introduced into the signal beam, and correlation measurements showed the meter phase and signal intensity to be strongly quantum correlated after the measurement.

Double QND measurements have recently been carried out by Bruckmeier, Hansen, and Schiller, working at the University of Constance in Germany (5), and by Bencheikh, Levenson, and co-workers at France Telecom (6). Both groups made their first measurements with optical parametric amplifiers constructed from frequency-doubling crystals. For their second measurement, the German group used a 50/50 beam splitter with squeezed light incident on the normally unused input port, whereas the French group used a second optical parametric amplifier. Both experiments showed each of the two successive back-action evasion measurements to give results quantum-correlated with the signal. Bruckmeier and co-workers further showed that the two successive measurements together improved the accuracy with which the signal could be known.

Important to an understanding of these and other QND measurements is the idea of quantum state preparation. Consider a typical signal to be measured: invariably, it will be in a quantum mechanical superposition of eigenstates of the observable to be measured. A measurement then selects out one of the eigenstates with a probability determined by the probability amplitude (assuming nondegenerate eigenstates). Usually, the measurement "demolishes" the wave function: A photodetector, for example, absorbs the light it measures. A QND measurement, if ideally strong, also selects out an eigenstate but leaves the wave function intact (this is sometimes described as the collapse of the wave function). If the signal is measured again, quantum measurement theory postulates that it will be in the same eigenstate. Therefore, QND measurements neither demolish nor change a quantum eigenstate. This property implies that two measurements are necessary to demonstrate QND: the first to prepare an eigenstate, and the second to verify its continued existence (see figure). Bruckmeier and co-workers have demonstrated a two-step quantum state preparation process that cumulatively narrows the distribution of final states, a weak version of QND in agreement with the postulates of quantum measurement theory.

Clearly, stronger QND measurements are desirable. Other aspects could be improved as well. For example, the measurements by Bruckmeier *et al.* were done with continuous waves, hard to define in simple quantum mechanical terms. Better from this standpoint are the results of the two French groups, which measure the properties of optical pulses. Better still would be optical solitons, quantum objects with well-defined particle and optical properties (7). A group at NTT Basic Research Labs in Japan, recently joined by a group at the University of Erlangen in Germany, has been pursuing this option, which allows consecutive photon number measurements of solitons in single optical fibers with very low loss (8). These measurements, however, all have the same failing: The number of quanta in the signals is large, typically 10^5 or more. Therefore, they lack conformity with the textbook criteria for observing quantum effects, namely that the number of quanta be small and that level spacings between eigenstates be readily discernible.

Resolution of these problems may come from QND experiments soon to be undertaken in low-temperature, high–quality factor microwave cavities by Brune, Haroche, and co-workers at l'Ecole Normale Superièure in Paris (9). Many ingredients for a QND measurement of one or a few quanta are already in place and tested: a cavity that can hold photons long enough for consecutive measurements, proven experimental techniques for probing the fields in the cavity by sending through single atoms and measuring their excitation afterwards, and proven capabilities for entangling the state of successive atoms in the cavity. Successful QND measurements with this apparatus could show both the collapse of superpositions of eigenstates to a single eigenstate and repeated observations of that eigenstate. Should this prove feasible, sensitive explorations of the fundamental postulates of quantum measurement theory will have taken, might we say, a quantum jump. Maybe the mystery at the heart of quantum mechanics will come to be seen as commonplace.

References

1. V. B. Braginsky, Yu. I. Vorontsov, K. S. Thorne, *Science* **209**, 547 (1980).
2. M. F. Bocko and R. Onofrio, *Rev. Mod. Phys.* **68**, 755 (1996).
3. See, for example, the "Special issue on Quantum Nondemolition Measurements," J. Mlynek, G. Rempe, S. Schiller, M. Wilken, Eds., *Appl. Phys. B* **64**, 123 (1997).
4. J.-F. Roch *et al.*, *Phys. Rev. Lett.* **78**, 634 (1997).
5. R. Bruckmeier, H. Hansen, S. Schiller, *ibid.* **79**, 1463 (1997).
6. K. Bencheikh, J. A. Levenson, Ph. Grangier, O. Lopez, *ibid.* **75**, 3422 (1995).
7. P. D. Drummond, R. M. Shelby, S. R. Friberg, Y. Yamamoto, *Nature* **365**, 307 (1993).
8. S. R. Friberg, S. Machida, Y. Yamamoto, *Phys. Rev. Lett.* **69**, 3165 (1992); S. Spälter, P. van Loock, A. Sizmann, G. Leuchs, *Appl. Phys. B* **64**, 213 (1997).
9. M. Brune, S. Haroche, J. M. Raimond, L. Davidovich, N. Zagury, *Phys. Rev. A* **45**, 5193 (1992); E. Hagley *et al.*, *Phys. Rev. Lett.* **79**, 1 (1997).

WEBWATCH

Planets not of our sun

http://www.obspm.fr/departement/darc/planets/encycl.html

Recent observations suggest the existence of planetary bodies orbiting stars far from our solar system, and the Extrasolar Planets Encyclopedia is a compilation of the current data. Made available by the Observatoire de Paris, the Encyclopedia presents physical data such as planetary mass and radius, orbital radius, inclination, eccentricity, and orbital period. In addition to general background information about detection methods, each object is thoroughly annotated with details about data sources, and in controversial cases, discussions of data interpretation in the literature.

Sharper molecular images

http://www.imb-jena.de/IMAGE.html

The Image Library of Biological Macromolecules contains images created from coordinate files at the Protein Data Bank of Brookhaven National Laboratory and the Nucleic Acid Database at Rutgers University. Hosted by the Institut für Molekulare Biotechnologie in Jena, Germany, the Image Library offers explanatory and background material to inform the user about its protein, RNA, DNA, and carbohydrate images. Images are available in GIF, PDF, and PostScript formats; some are also available in Virtual Reality Modeling Language (VRML) format, which allows viewing them from different angles.

Software tools for chemists

http://www.csir.org/

The Chemistry Software and Information Resources site has many links to computational tools in quantum chemistry and visualization. The site is hosted by Syracuse University and includes applications that run on desktop computers as well as powerful workstations. The site also provides access to a large number of chemistry-related mailing lists that are archived and searchable.

Edited by David Voss

Readers are invited to suggest excellent scientific Web sites by e-mail to editors@aaas.org.