GENERAL PHYSICS

I. MOLECULAR BEAMS*

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RESEARCH OBJECTIVES

Three kinds of research are carried on in the Molecular Beams Group.

1. High-precision studies of atomic and molecular radiofrequency spectra.

2. Experiments directed toward establishing precise frequencies generated by atomic clocks of proved independence from external influence, and the intercomparison of these frequencies.

3. Experiments such as

   (a) measurement of the velocity of light in terms of atomic standards,

   (b) search for a charge carried by molecules, both by gas efflux and beam deflection methods,

   (c) study of atomic beams from liquid helium,

   (d) an experiment on an aspect of continuous creation.

These experiments are described in more detail below.

J. R. Zacharias, J. G. King, C. L. Searle

1. RF Spectra

Hyperfine structure of the 1-1, 2-2, 3-3, and 3-2 inversion transitions of $N^{14}H_3$ has been measured with the two-cavity maser spectrometer. The Hamiltonian and coupling system of Gordon[1] has been used to describe the spectra, and fits have been carried out to determine the parameters in his theory. Small discrepancies of approximately 0.5 kc are present between theory and experiment.

S. G. Kukolich

References

1. J. R. Gordon, Phys. Rev. 99, 1253 (1955).

*This work is supported by the Joint Services Electronics Programs (U.S. Army, U.S. Navy, and U.S. Air Force) under Contract DA 36-039-AMC-03200(E).

2. Molecular Clocks

Work on this program has been temporarily suspended while details of the NH_3 inversion spectrum are investigated as mentioned above.

S. G. Kukolich

3. Atomic Clocks

The 10-ft Cs clock has been used with an electric field in an attempt to observe the electric dipole moment of the Cs atom previously reported.[2] Data obtained thus far establish a limit of $0.8 \pm 8 \times 10^{-20}$ electron-cm. Meanwhile, two duplicate 10-ft clocks are being constructed for use in the intercomparison program (see below).

C. O. Thornburg, Jr.

References

1. T. G. H. Sanders and E. Lipworth, Phys. Rev. Letters 13, 718 (1964).

4. Intercomparison of Clocks

The intercomparison experiment involving two commercial beam tubes coupled to electronic equipment employing frequency impulse modulation has been completed. Detailed intercomparisons have been made by measuring the phase difference between the clocks, and using a computer to calculate the phase spectral density and the mean-square frequency fluctuation as a function of averaging time. Final results indicate a stability of 5 parts in 10^{12} for a 1000-second averaging time, a result quite consistent with the measured signal-to-noise ratio for these particular beam tubes.

The same method of intercomparison will now be used to measure the performance of the new clocks described above.

C. L. Searle, R. S. Badessa

5. Decelerator for Molecules

This apparatus makes use of nonuniform pulsed electric fields for slowing down molecules to smaller velocities than have hitherto been observed. The construction of the apparatus is complete and a beam has been observed.

R. Golub, G. Guttrich

6. Velocity of Light

By investigating the resonances of an adjustable precision microwave cavity for both light and microwaves, one can, with suitable corrections, establish the ratio of the two wavelengths that are used; this can be interpreted either as the ratio of light in fundamental constants or (through the usual standards) as the velocity of light. Preliminary results obtained by using a Nitrogen atmosphere have shown a reproducibility of 7 parts in 10^7. Multiple measurements will now be made in Helium.

M. A. Yaffee, C. L. Searle, J. R. Zacharias

7. Neutrality of Atoms

We have performed gas efflux and atomic-beam deflection experiments, both designed to reveal a charge unbalance in supposedly neutral atoms. In both cases, we are attempting to analyze and understand in detail the large bulk of data obtained and to determine whether certain persistent effects are of any fundamental interest. One of us (K. W. B.) has collaborated with C. G. Shull at the M. I. T. reactor in setting a new upper limit on the charge carried by the neutron.

K. W. Billman, J. G. King

8. Helium Beams

Apparatus has been constructed and operated successfully to yield time-of-flight velocity distributions for helium gas sources in the temperature range 3-4.2°K. Investigations are proceeding to lower temperatures, and a comparison of the gas data with velocity distributions of atoms evaporating from a liquid source is planned for the future.

W. D. Johnston, Jr.

9. Mercury Boiling Experiment

In this experiment we seek to place an upper limit on the appearance of Hydrogen in Mercury. The apparatus is essentially a Mercury still with a scanning mass spectrometer. The object of the experiment is to test a remotely conceivable density-dependent continuous creation hypothesis. A new small apparatus containing less Hydrogen is being developed.

E. F. Taylor, J. G. King

A. LOW-TEMPERATURE HELIUM BEAM EXPERIMENT

Time-of-flight velocity distributions from a helium gas source have been obtained for source temperatures of 3-4.2°K. A signal-to-noise ratio of 10:1 at the peak of the distribution has been obtained, with a chopper admittance time of 0.75 msec and a detector resolution time of 0.25 msec. The distribution curves retain significance down to one-third of the most probable velocity.

The distributions are in qualitative agreement with expectations based on the assumptions of a Maxwell-Boltzmann distribution in the source and an effective detector size inversely proportional to the kinetic energy of the beam particles. Quantitative comparisons will be made after the results of a computer calculation of the theoretical curves, which is now in progress, are obtained.

Data at lower temperatures are now being taken with the gas source. The ultimate goal is a comparison of the gas source data with data derived from a beam formed directly from evaporating liquid helium. Only a minor modification to the present apparatus is required to permit observation of the evaporating liquid source; this will be carried out soon.

W. D. Johnston, Jr.

B. SOME ASPECTS OF THE THEORY AND MEASUREMENT OF FREQUENCY FLUCTUATIONS IN FREQUENCY STANDARDS

[This report summarizes a paper that is to appear in the February 1966 issue of Proc. IEEE.]

Precision quartz oscillators have three main sources of noise which contribute to frequency fluctuations: thermal noise in the oscillator, additive noise contributed by auxiliary circuitry such as AGC, and fluctuations in the quartz frequency, as well as in the reactive elements associated with the crystal, leading to an f^{-1} type of power spectral density in frequency fluctuations. Masers are influenced by the first two types of noise, and probably by the third.

The influences of these sources of noise on frequency fluctuation versus averaging time measurements is discussed. The f^{-1} spectral density leads to results that depend on the length of time over which the measurements are made. An analysis of the effects of finite observation time is given.

The characteristics of both passive and active atomic standards obtained by using a servo-controlled oscillator are discussed. The choice of servo time constant influences the frequency fluctuations observed as a function of averaging time; it should be chosen for best performance with a given quartz oscillator and atomic reference.

The conventional methods of handling random signals, that is, variances, autocorrelation, and spectral densities, are applied to the special case of frequency and phase fluctuations in oscillators, in order to obtain meaningful criteria for specifying oscillator frequency stability. The interrelations between these specifications are developed in the course of the paper.

L. S. Cutler, C. L. Searle

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