AIP | Review of Scientific Instruments

A Gas-Phase EPR Cavity

I. M. Brown and R. J. Richardson

Citation: Review of Scientific Instruments **44**, 77 (1973); doi: 10.1063/1.1685965
View online: http://dx.doi.org/10.1063/1.1685965
View Table of Contents: http://scitation.aip.org/content/aip/journal/rsi/44/1?ver=pdfcov
Published by the AIP Publishing

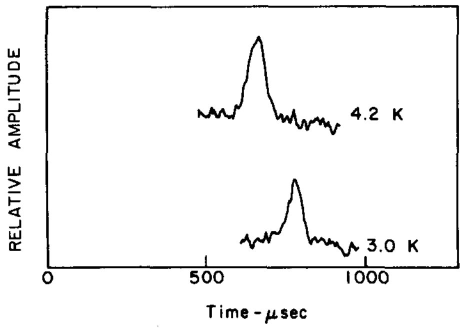

FIG. 2. Time-of-flight results for the source at various temperatures. The signals were obtained by signal averaging with a resolution of 4 μsec per channel.

(iii) allows for rapid cool-down and warm-up, and (iv) it can be pumped to obtain temperatures below 4.2 K.

The nozzle is a watch jewel with a 26 μ diam hole sealed in a brass holder which makes intimate contact with the cold finger through a flat indium gasket.[2] A stainless steel tube 0.031 cm i.d., by 0.056 cm o.d. wrapped several times around the cold finger is used for gas precooling and helium gas transfer into the stagnation region of the source. For the cold finger, it is optional whether to use a liquid nitrogen cooled shield around the finger, however, in this work it was used both as a radiation shield and as the support for the skimmer (0.05 cm diam). The nozzle–skimmer distance could be changed by moving the skimmer and it was initially adjusted at room temperature to give maximum signal. For most of the measurements this was set at 0.195 cm. An electron bombardment detector located 14 cm from the chopper was used to detect the beam.

The time-of-flight signals for this source at various temperatures are shown in Fig. 2. For the case where the cold finger was pumped, the temperature was obtained from the time-of-flight information. This gave $T=3.0$ K. The results of time-of-flight are shown in Table I. The velocity corresponds v_m to that obtained from the maximum in the time-of-flight results. Additionally the absolute beam density was measured for different gas flow rates and these are also indicated in Table I.[3] The results of Vyse *et al.* of beam intensity vs stagnation pressure were also confirmed.[4]

TABLE I. Experimental results.

T K	v_m m/sec	HWHM[a] $\Delta v/v$	$N\times10^{-12}$ [b] cm^{-3}	Total He flow rate atm ml/min at 300 K
4.2	208	0.059	2.2	9.0
3.0	178	0.046	4.6	3.3

[a] Uncorrected for slit chopping function which was 22 μsec in width (FWHM).
[b] Located 2.5 cm downstream of nozzle.

Because of the very small relative velocity between helium atoms in the beam at these low temperatures, there may be considerable self scattering.[5] One possible means of observing this is to measure beam intensity as a function of nozzle–detector distance. Between the nozzle–detector distances of 2–6 cm the $1/r^2$ relation appeared satisfied. It is still possible and quite likely that self scattering could be observed for distances less than 2 cm, but this could not be checked in this work.

*Research sponsored by the Air Force Office of Scientific Research, Office of Aerospace Research, USAF, under Grant No. AFOSR-71-2070.
[1]Air Products and Chemicals Inc., Allentown, Pa. 18103; Cryotip system model LT-3-110.
[2]B. Baratz, Ph.D. thesis, Princeton University, 1967; Watch jewel obtained from William Langer Jewel Bearing Plant, Rolla, N. Dakota 58367.
[3]R. S. Grace, D. P. Morrow, J. P. Aldridge, and J. G. Skofronick, Rev. Sci. Instrum. **43**, 696 (1972).
[4]R. Vyse, D. Axen, and M. K. Craddock, Rev. Sci. Instrum. **41**, 87 (1970).
[5]I. Estermann, O. Simpson, and O. Stern, Phys. Rev. **71**, 238 (1947).

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 44, NUMBER 1 JANUARY 1973

A Gas-Phase EPR Cavity*

I. M. Brown and R. J. Richardson
McDonnell Douglas Research Laboratories, McDonnell Douglas Corporation, St. Louis, Missouri 63166
(Received 5 July 1972; and in final form, 4 October 1972)

The design of an X-band cylindrical TE_{011} cavity resonator with a 25 mm diam axial access hole for gas-phase EPR studies is described. The empty cavity is tunable over a frequency range of at least 8.0–10.0 GHz and critical coupling is attained over this range with a novel variable coupling device.

In this Note we describe the design details and fabrication of a cylindrical TE_{011} X-band cavity for gas-phase EPR studies. This design incorporates the following important features: (1) A 25 mm access port to accommodate a quartz gas-flow tube; (2) tunability from at least 8.5–9.5 GHz; (3) adequate coupling of the desired mode over this

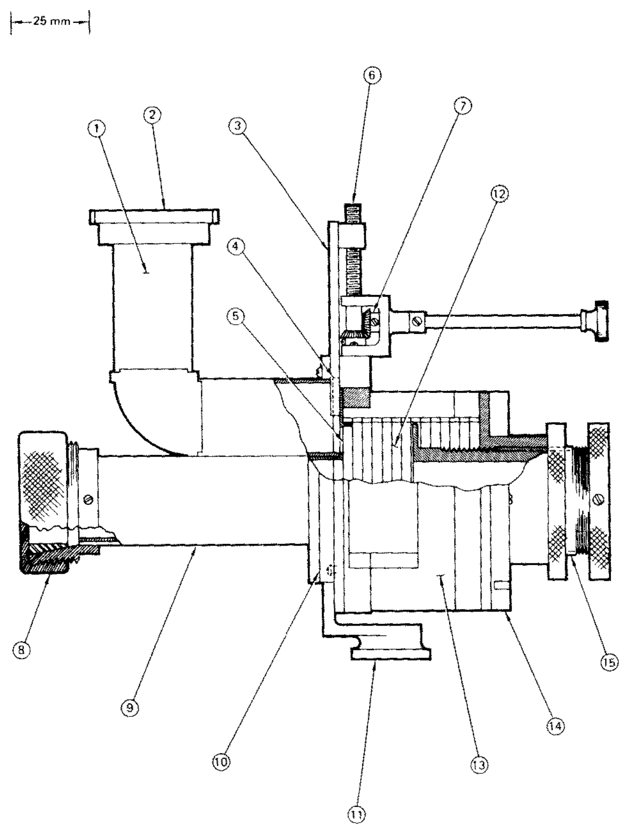

FIG. 1. TE_{011} cylindrical EPR cavity for gas-phase experiments: (1)—X-band waveguide; (2)—UG-39/U waveguide flange; (3)—nylon shutter; (4) Lucalox disk; (5)—coupling hole; (6)—threaded shaft; (7)—miter gear; (8)—collet to clamp sample tube; (9)—bushing to prevent microwave leakage; (10)—modulation coil holder; (11)—bracket for modulation coil connector; (12)—copper rings; (13)—molded epoxy; (14)—coil holder; (15)—threaded plunger.

total frequency range; (4) adequate penetration of the 100 kHz magnetic field modulation; (5) a high Q factor; (6) a cavity o.d. less than the 75 mm magnet gap; and (7) external modulation coils to permit air cooling at high power levels.

The construction details are shown in Fig. 1. A unique cylindrical laminated wall design,[1] consisting of 14 stacked copper rings each 50 mm in diam, 1.6 mm. thick, and 3.2 mm in depth, allows adequate penetration of the 100 kHz magnetic field modulation. These rings were sprayed to a thickness of 0.025 mm with a clear acrylic coating to suppress spurious modes and the 100 kHz eddy currents. The copper rings were held in a split aluminum mold and cast in epoxy resin (Miller Stephenson type No. 907) to add mechanical strength and to prevent wall vibrations.

The cavity is tuned by a plunger turning on a 0.47 turns/mm thread. A gap of 0.5 mm between the plunger head and the cylindrical cavity wall permits the maximum cavity Q since there are no microwave radial wall currents at the endplates for the TE_{011} mode. The empty cavity can be tuned with variable insertion of this plunger-head from at least 8.0–10.0 GHz and from 7.5–9.5 GHz with a 24 mm diam quartz tube (22 mm i.d.) inserted in the 25-mm access port. The maximum unloaded Q was 16 000. This plunger head design and the laminated wall construction provide suppression for most of the spurious modes other than the TE_{011}; however, several unidentified modes were observed by varying the cavity length and coupling mechanism. Fortunately, most of these spurious modes are always sufficiently distant (>800 MHz) from the TE_{011} mode that they do not affect its Q. However, a fixed frequency mode exists at 9.4 GHz in the empty cavity which deteriorates the Q of the TE_{011} mode when the frequency is within ~300 MHz of it. With a 24 mm diameter quartz tube in the cavity this spurious resonance is lowered to 8.8 GHz.

Modulation coils (57 mm×67 mm) with 100 turns of No. 28 Bondeeze wire are mounted on the cavity exterior. With the laminated wall construction it is possible to generate a peak-to-peak modulation of 5 G in the cavity when the coils are driven by the Varian V4560 100 kHz power amplifier. (The coils were wound to match the output impedance of this instrument.) The homogeneity of the magnetic field modulation is such that over the entire sample volume this field is always within 80% of its maximum value measured at the center of the cavity.

The waveguide feed is coupled to the resonant cavity through an iris in the top plate. Variation in cavity matching is accomplished by a nylon shutter containing a Lucalox[2] disk (3 mm thick, 9 mm diam, dielectric constant =9) which can be moved across a plane in the waveguide side of the iris. A shaft and miter gear arrangement provide easy manipulation of cavity matching even when the cavity is in the magnet gap. This adjustment mechanism produces extremely smooth coupling changes.

Because of the wide range of coupling attainable with the

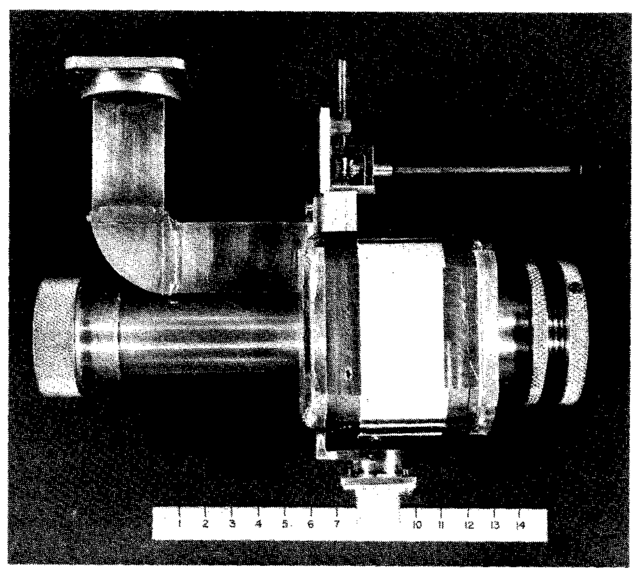

FIG. 2. The assembled cavity.

matching mechanism described above, it is possible to achieve critical coupling through the end wall despite the 25 mm diam sample ports. This end wall coupling and laminated wall construction are convenient for experiments combining EPR and optical studies where two radial optical ports are used to irradiate and monitor the luminescence of the sample *in situ*.

Figure 2 is a photograph of the assembled cavity.

*This device was developed under U. S. Army Missile Command Contract No. DAAH01-71-C-0748.

[1]I. M. Brown and D. J. Sloop, Rev. Sci. Instrum. **38**, 695 (1967).

[2]Sintered αAl_2O_3, General Electric Co., Lamp Division.

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 44, NUMBER 1 JANUARY 1973

Digitized Magnetic-Field Sweeper for ESR Spectrometer

Takehiko Hidaka

Electrotechnical Laboratory, 5-4-1, Mukodai, Tanashi-shi, Tokyo, Japan

(Received 21 July 1972)

A digitized magnetic-field sweeper is described that is designed for the signal-averaging digital computer aided ESR spectrometer.

A recent technical improvement for ESR spectroscopy has been the use of signal-averaging digital computer to enhance the signal-to-noise ratio.[1,2] If the ESR measurement is repeated n times and the signal is averaged by the computer, then the signal-to-noise ratio may be $\sqrt{n}$ times enhanced. In our system, we need good resettability of the magnetic field during the respective measurements, for high resolution ESR spectroscopy. In the use of the digital computer, the ESR output is sampled and analog-to-digital converted (Fig. 1). Then the magnetic field at the sampling point should be equal at the repeated field sweepings.

This report describes the digitized magnetic-field sweeper controlled by the clock pulse, which at the same time controls the analog-digital converter and digital computer.

Figure 1 shows the experimental setup. Magnetic-field strength is detected by a temperature-stabilized Hall element and referenced wlth the standard voltage. Sensitivity of Hall element is 1 V/20 kG. The standard voltage is supplied from the 1.3 V mercury cell and 10-turn helical potentiometer. The helical potentiometer is driven by the pulse motor, whose step is 1.8° per pulse. The standard voltage is thus digitized. The difference voltage between the standard and the output of the Hall element is amplified and drives the dc current controller (using power transistor 2SC433). If the gain of the servo loop is high enough, the magnetic field is stabilized and digitized. The pulse motor is driven by the clock pulse. The clock pulse is 0.1–10 pps, which controls the analog–digital converter and the signal-averaging digital computer.

The result is shown in Fig. 2. Figure 2(a) shows the long

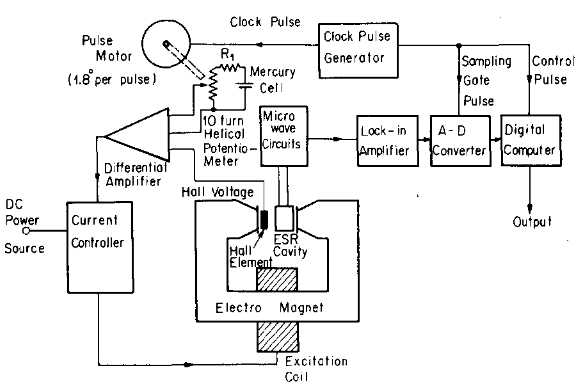

FIG. 1. Experimental setup for digitized magnetic-field sweeper.

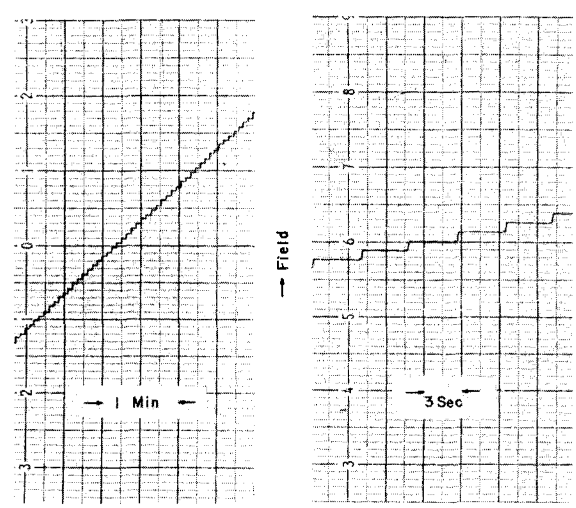

FIG. 2. Controlled characteristics. (a) Long-term linearity and (b) short-term waveform of magnetic field. A step is 1 G.