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An integrated, high vacuum, beam modulation device

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Abstract A piezoelectric element employed as a vibrating-reed beam modulator inherently possesses characteristics which allow the device to operate as a self-maintaining oscillator. The electrical drive, resonant frequency and controlling feedback are all integral properties of the multimorph. The resulting chopper is remarkably simple to make, highly stable and ideally suited for high vacuum applications.

1 Introduction

The detection of short-lived transients in gas-phase reactions can be achieved by sampling with a supersonic molecular beam probe (Foner and Hudson 1953). The beam produced in the differential pumping system is well defined and collision free. The composition of the beam can be determined by passing the beam into the ionization source of a mass spectrometer and counting the ions produced by their different mass and charge characteristics. The system also produces a large background signal due to the scattering and normal diffusion of the molecules through the sampling and collimating apertures which can approach in intensity the signal due to the beam. As the transient species normally constitute a fraction of the beam composition, their detection presents real problems in signal recovery from high noise levels. The techniques now routinely applied, phase sensitive detection and ion counting, both require a device to compare beam on–beam off situations. This is usually a mechanical chopper, either a vibrating reed or a rotating toothed or slotted disc. The geometry and high vacuum requirements of these sampling systems can preclude the rotating sector disc, and variations on the vibrating reed or tuning fork have usually been chosen. The design of such a chopping device requires consideration of three separate aspects; maintaining the vibration of the reed, choice of resonant frequency and stability of reed material, and monitoring the reed movements to provide a reference output for the lock-in amplifier. Present chopper designs use magnetic coils to drive the reeds and the external driving oscillator also provides the reference frequency.

Frequency drifts due to temperature and pressure in the vacuum system can be compensated by using a transducer to monitor the reed vibrations (Leckenby *et al.* 1964), and using this as a reference output. The amplified output has been employed (Ormrod and Patterson 1967) to provide a locked-in driving frequency. A piezoelectric element has also been employed as a resonant reed (Allan 1970).

We report here an approach in which the drive, reed and feedback elements are all integrated into a single active component, thus simplifying the system considerably while maintaining all the advantages of stability and vacuum compatibility.

2 Construction

Due to the inherent simplicity of the design the chopper assembly is straightforward. The piezoelectric rod (Vernitron Ltd PZT-5B multimorph) was supplied as a thin rod 0·6 mm × 1·6 mm × 38 mm and is clamped between a pair of aluminium electrodes mounted on $\frac{1}{8}$ in stainless-steel rods. These also provide the electrical connections to the two flat silvered faces through ceramic insulators in a standard UHV flange. The mounted element is shown in figure 1. To obtain a suitably large amplitude without overstressing the multimorph, the reed would have to be about 10 cm long, which corresponds to a resonant frequency of around 40 Hz. From our noise spectrum analysis the mechanical resonance of the chopper was chosen to be about 127 Hz. A shorter length of multimorph was thus employed with a light aluminium extension which ended in a shaped flag.

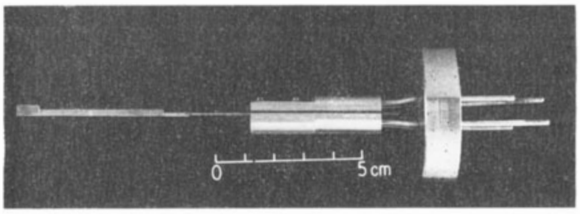

Figure 1 The complete chopper mounted on a UHV flange

3 Operation

The device was tested as an optical chopper which interrupted a laser beam on an optical bench. This allowed the phase shift characteristics to be monitored, and the mechanical and electrical components produced by an external oscillator to be observed. A rapid change of phase relationship was shown when the reed was driven around its resonant frequency. This means that for good stability a self-maintaining system employing feedback is necessary.

Below resonance the phase shift is fairly constant and the device is usable as a driven element from an external oscillator (Allam 1970), although in prolonged trials in high vacuum it showed a marked tendency to drift. The observed operating characteristics were a high impedance even at resonance, a low Q factor (approximately 100), very low power requirements and good temperature stability. No appreciable ageing has so far been noticed with the device.

The operating characteristics are thus virtually independent of temperature, and as the Curie point of the PZT multimorph is well above 300°C the device can be used in systems which need baking.

4 Self-maintaining circuit

It was found that the self-maintaining circuit can easily be derived from a two transistor amplifier. This fulfills all the necessary conditions for gain, high input impedance and low output impedance.

The circuit is arranged as a closed loop system utilizing the multimorph as the positive feedback element. The amplifier gain is stabilized by a feedback resistor R (figure 2) and a

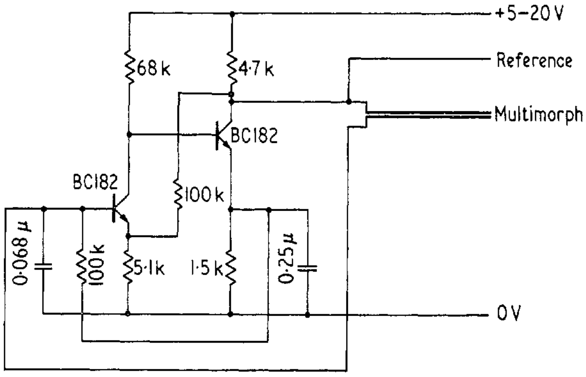

Figure 2 The self-maintaining circuit

high frequency roll off provided by the input shunt capacitance C, which prevents oscillations in higher frequency modes. The reference signal was fed into the Brookdeal lock-in amplifier (401 A). Oscillator amplitude is simply varied by adjusting the voltage applied to the circuit.

The only frequency-conscious element in the system is the reed, the lock-in amplifier being sensitive only to phase. No filters or tuned amplifiers are necessary as the 401 A has a wide range and good offset capability.

The whole device can easily be made compact and self-contained.

5 Conclusions

This system represents a simplified, integrated approach to high vacuum beam chopping. The power required is minimal. The device is stable, temperature independent and bakeable. The device is very compact and inexpensive to construct. We have used this self-maintained chopping system in a molecular beam system continuously over a period of time and find it represents a useful low cost, low frequency chopping system to be recommended for systems with stringent physical constraints.

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