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Balanced bias differential current amplifier circuit for detection of laser induced multiphoton ionization

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TABLE I. Relative intensities and concentrations at 880 m s^{-1}.

	CH_2	Cs	CH_2I	CH_2I_2
Relative ion intensities	0.15	1.0	0.068	0.0045
σ_{ioniz} (nm^2)[a]	0.024[b]	0.088[c]	0.092[b]	0.16[b]
Relative concentrations	0.55	1.0	0.065	0.0025

[a] For electron bombardment at 50 eV (except for the H contribution).
[b] Calculated by the method of Ref. 11, using data of Mann.[7]
[c] From Ref. 8.

species and much lower for the light species than for the principal component in the mixture, M. We presume that either thermal accommodation is incomplete or that some mass flow streaming effect is present. We noted a carbon deposit which built up on the orifices of the needle and oven, eventually blocking the tubes. Experiments with inert gas diluents, pyrex hypodermic needles, a tungsten wire "scraper," and variation of the needle and oven orifice diameters were attempted, but the longest running time has been 1 h. (Recently, Y. T. Lee suggested[10] connecting an oxygen atom source to the hypodermic needle inlet as an intermittent procedure to clean off the carbon deposit.)

The relative ion intensities (not normalized) at 880 m s^{-1} (the maximum of the high speed CH_2 peak) and estimated ionization cross sections were used to calculate the relative concentrations of the main beam species. These are shown in Table I.

CH_3^+ and CH_4^+ were usually not observed, unless there was a high flow rate of CH_2X_2.

It is expected that the same principle may be employed to produce beams of CH or CH_3.

[1] A. H. Laufer and A. M. Bass, J. Phys. Chem. **78,** 1344 (1974).
[2] M. J. Pilling and J. A. Robertson, J. Chem. Soc. Faraday Trans. **73,** 968 (1977).
[3] H. Kollmar and V. Staemmler, Theor. Chim. Acta **51,** 207 (1979).
[4] B. Zurawski and W. Kutzelnigg, J. Am. Chem. Soc. **100,** 2654 (1978).
[5] W. W. Schoeller and E. Yurtsever, J. Am. Chem. Soc. **100,** 7548 (1978).
[6] C. E. H. Bawn and C. F. H. Tipper, Disc. Far. Soc. **2,** 104 (1947).
[7] A. E. Grosser, Rev. Sci. Instrum. **38,** 257 (1967).
[8] F. Kalos and A. E. Grosser, Rev. Sci. Instrum. **40,** 804 (1969).
[9] F. Kalos and A. E. Grosser, Chem. Phys. Lett. **6,** 537 (1970).
[10] Y. T. Lee (private communication).
[11] F. W. Lampe, J. L. Franklin and F. H. Field, J. Am. Chem. Soc. **79,** 6129 (1957).
[12] J. B. Mann, in *Recent Developments in Mass Spectroscopy*, edited by K. Ogato and T. Hayakawa (University Park, Baltimore, 1970), p. 814.
[13] R. H. McFarland and J. D. Kinney, Phys. Rev. **137,** A1058 (1965).

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A circuit is described for the production of an amplified, single-ended output signal from a well-shielded multiphoton ionization cell.

Resonant multiphoton ionization of molecules (MPI) is a rapidly growing field of research.[1] The potential of this process for providing unique information about molecular electronic structure has been amply demonstrated.[2–6] It has also shown promise as a highly selective detection method with sensitivity and time and space resolution rivaling that of laser induced fluorescence. Moreover, by all indications, the process is rather general.

One of the most significant advantages of spectroscopic measurement by MPI is that it simply involves the detection of ions. A number of well-established, sensitive methods are available for doing this. However, the implementation of such methods in noisy laser laboratory environments can present difficulties. For example, the use of a conventional single-ended current amplifier with unbalanced biasing requires that the shield be part of the signal path. This can hamper the extraction of a high quality MPI signal because in this configuration radio frequency interference (RFI) is easily coupled into the circuit through the shield.

Here we report a new, highly noise-resistant detection circuit for MPI that is both convenient to use and inexpensive. It consists of a balanced bias differential current amplifier buffered by a unity gain difference amplifier which drives a single-ended output. A schematic of the circuit, including bias supply and MPI cell, is shown in Fig. 1.

In operation this arrangement effectively produces a differential signal from symmetrically biased plates by using two batteries arranged in opposite polarity. This allows the entire circuit, including both collection plates, to be shielded all the way to the single-ended output.

The high-frequency response of the circuit has been enhanced by isolating the power supply batteries by resistors, R_1 through R_4 and effectively using the two capacitors, C_1 and C_2, as high bandwidth batteries.

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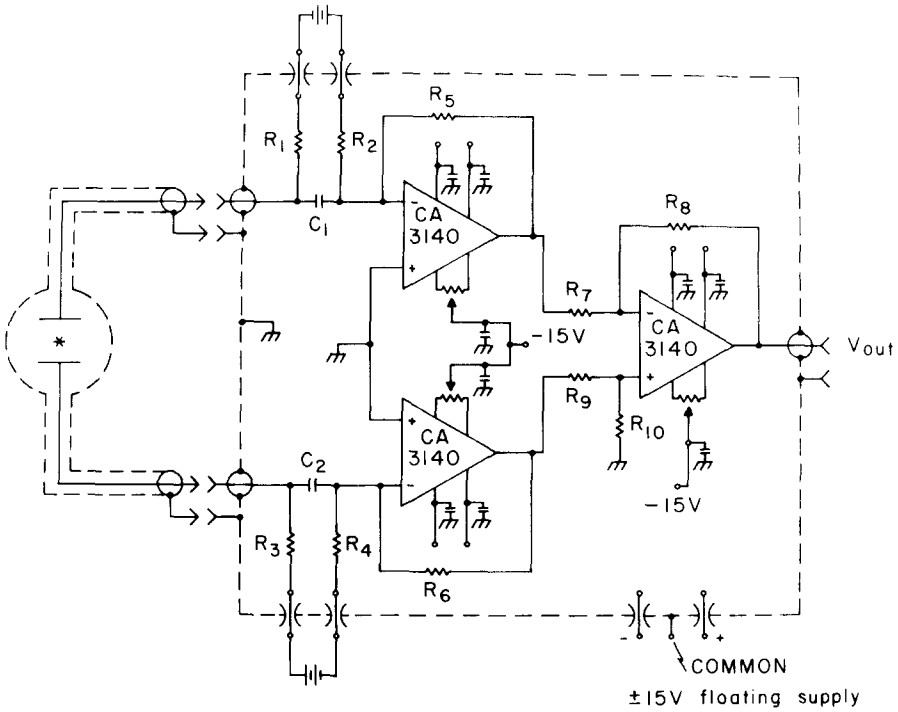

FIG. 1. Schematic circuit diagram for the balanced bias differential current amplifier showing its placement in the overall detection circuit for a multiphoton ionization experiment. Chassis ground as indicated is the ground plane of the circuit board. Note that $R_1 = R_2 = R_3 = R_4 = 1.5$ MΩ; $C_1 = C_2 = 0.02$ μF, 1 kV; $R_5 = R_6 = 10$ MΩ; $R_7 = R_8 = 20$ kΩ; $R_9 = R_{10} = 10$ kΩ; Offset trim 10-kΩ pot.; all bypass capacitors 0.01 μF; bias supply feed-through capacitors 0.01 μF, 1 kV; op amp power supply feed-through capacitors 6.8 μF, 35 V.

A typical time duration for a multiphoton ionization pulse in our application with 1.5-cm plate spacings is 5 μs fwhm. During that time, of the order of 1×10^6 ions may be produced. The current flow under such conditions would be 10^{-7} A, so discharge of the capacitors is negligible.

Each side of the differential current signal produced by the ionization pulse is amplified by a CA3140 FET input op amp. A particularly important aspect of this circuit is that, in the arrangement shown, the outputs of these sensing op amps must each supply a current equaling that of the signal in order to close the current loop. The voltage generated will be whatever is necessary to cause the required current to flow across resistors R_5 and R_6. In the present application, with these set at 10 MΩ the current to voltage conversion gain is 10^7 V per ampere.

The feedback resistors, R_8 and R_{10}, have been set to equal R_7 and R_9 respectively in order to produce unity gain for the difference amplifier. As a result the difference output is equal to twice the signal current multiplied by the conversion gain of the sensing amplifiers. Setting R_9 and R_{10} each to one-half R_8 gives both arms the same input impedance. The dc drift in the output has been observed to be less than a few tens of millivolts over a day's experiment.

In present usage bias power is supplied by a pair of 90-V batteries, though high dc stability is not really necessary and any moderately well-regulated supply would do. The output for conditions of ion production and amplifier gain specified above is about 1 V per 10^6 ions.

We have found this circuit well suited for conventional boxcar signal averaging. We are in the process of expanding our MPI detection capabilities by incorporating this amplifier in a computer based system that records both ionization signal and laser intensity for each laser shot. Details concerning this system as well as the results of our measurements will appear in forthcoming publications.

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[1] See for example: D. H. Parker, J. O. Berg, and M. A. El-Sayed, *Advances in Laser Chemistry*, Springer Series in Chem. Phys. Vol. 3, edited by A. H. Zewail (Springer-Verlag, New York, 1978).
[2] P. M. Johnson, M. R. Berman, and D. Zakheim, J. Chem. Phys. **62,** 2500 (1975); P. M. Johnson, *ibid.* **62,** 4562 (1975); P. M. Johnson, *ibid.* **64,** 4143 (1976); D. Zakheim and P. Johnson, *ibid.* **68,** 3644 (1978); P. Cremaschi, P. M. Johnson and J. L. Whitten, *ibid.* **69,** 4341 (1978).
[3] C. Tai and F. W. Dalby, Can. J. Phys. **56,** 183 (1978).
[4] K. K. Lehmann, J. Smolarek, and L. Goodman, J. Chem. Phys. **69,** 1569 (1978).
[5] L. Zandee, R. B. Bernstein, and D. A. Lichtin, J. Chem. Phys. **69,** 3427 (1978); L. Zandee and R. B. Bernstein, *ibid.* **70,** 2574 (1979).
[6] D. L. Feldman, R. K. Lengel, and R. N. Zare, Chem. Phys. Lett. **52,** 413 (1977).