Schlieren Optics and the Index of Refraction of a Gas

In this experiment you will investigate two effects associated with the index of refraction of a gas. The first part of the experiment is quantitative and involves interference of light waves; the second part is qualitative and involves refraction of light rays. *Before you come to lab,* please read about classical electron theory in Griffiths, Section 9.4.3.

I) Index of refraction of a gas

In this part of the experiment you will determine the index of refraction of various gases by observing the fringe shift that results when the gas is added to or removed from one arm of a Michelson interferometer. Why does the fringe shift occur? Show that if the gas is confined in a cell of length L and has an index of refraction n, the number of fringes that go by when the cell is evacuated is:

$$N = \frac{2L(n-1)}{\lambda} \quad .$$

Use a laser (with a microscope objective to diverge the light) as the source for illuminating the interferometer. The wavelength of the light from a He-Ne laser is 632.8 nm. Adjust the mirrors so you get good fringes with the cell filled with air at atmospheric pressure. Then pump the air out slowly, count the fringes, and determine n. You may find it easier to pump the air out first and count fringes as you let it bleed back in. What is the relationship between pressure and index of refraction? The length of the cell is 50.70 mm. Repeat the measurement for at least one other gas.

Cautions:
1) Do not pressurize the cell above atmospheric pressure.
2) Do not mess around with gas cylinders without prior instruction.
3) After turning the vacuum pump off, always bleed air into it.
4) Pump out the line from the gas cylinder before filling the gas cell.

II) Schlieren Optics

A Schlieren optics setup allows you to observe an image of small index of refraction gradients in a gas (the room air in the present case). Aim the beam from a laser (with a spatial filter) at the 6" diameter, 60" focal length concave mirror. The reflected beam should illuminate a second mirror 4 or 5 feet away. In the region between the mirrors the beam should be nearly collimated. After leaving the second mirror, the beam is focused about 5 feet away, where a razor blade is located. The beam then continues and illuminates a screen on the wall. The stage on which the razor blade is mounted allows precise motion both

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along the beam axis and perpendicular to it. Adjust the position of the razor blade until you are cutting into the light beam exactly at the focus. (Can you think of an easy way to tell whether you are in front of the focus or behind it? The tolerance here is measured in thousandths of an inch.) Ideally the bright spot would dim uniformly as the blade cuts into the beam at the focus. Try to achieve this behavior as well as you can.

If nothing disturbs the light beam as it passes through the optical system, all the light passes (nearly) through the focus and part of it is "scraped off" by the edge of the razor blade, resulting in a uniform spot. If, however, the index of refraction of the gas through which the light passes is not uniform (i.e., there are index of refraction gradients), then some of the rays will be refracted so that they strike the razor blade, and the corresponding parts of the projected spot will become darker. Other rays will be refracted so that they miss the razor blade entirely resulting in brighter regions within the spot. By this mechanism an image of the index of refraction gradients is formed.

Use the Schlieren setup to investigate the index of refraction gradients produced by a variety of processes. Some suggestions are: heat from a soldering gun, heat from your hand, a candle, a jet of gas, etc., etc. Make up AT LEAST one experiment of your own.

R.R.C.	4/3/83
S.J.H. rev.	1/15/91
R.R.C. rev.	3/9/94
C.E.C. rev.	2/19/95