Tunable Infrared Source by Difference Frequency Mixing Diode lasers and Diode pumped YAG, and Application to Methane Detection

S. Waltman[2], K. Petrov[1], U. Simon[1],
L. Hollberg[2], F. Tittel[1], and R. Curl[1]

[1] Departments of Electrical and Computer Engineering, and Chemistry
Rice University, Houston, Texas 77251-1892

[2] National Institute of Standards and Technology
325 Broadway, Boulder CO 80303
fax 303-497-7845

Tremendous potential exists for the application of diode laser sources for high sensitivity detection of atoms and molecules. Some of the obvious applications include pollution monitoring, medical diagnostics, industrial process monitoring, and analytic and atmospheric chemistry applications. Room-temperature, tunable diode laser sources provide the opportunity for constructing compact, transportable instrumentation. Unfortunately the wavelengths of most of the atomic and molecular transitions are not directly accessible with commercially available, room-temperature diode lasers. In particular many of the important molecular transitions are in the mid-infrared spectral region. However, this spectral region is accessible with difference-frequency-generation (DFG) using visible and near-IR lasers.

We have constructed a DFG system that generates about 10 μW of IR that is tunable between 3.1 and 3.4 μm (3076 to 3183 cm^{-1}). The basic structure of the DFG system is diagramed in Fig. 1. The input frequencies come from a diode laser, tunable near 800 nm, and a diode-pumped YAG at 1064 nm. The difference frequency radiation is generated in a 5 mm long $AgGaS_2$ crystal that is located at the waist of a ring buildup cavity. The buildup cavity is used to enhance the power of the 1064 nm beam. The diode laser light is collinear with the 1064 nm beam but is not resonated in the ring cavity. This arrangement allows us to tune the diode laser and hence the DFG wavelength without having to synchronously track the buildup cavity resonance frequency. The broad wavelength coverage between 3.1 and 3.4 μm is accomplished with a single diode laser using a grating in an extended-cavity configuration. The mixing crystal is angle tuned using a rotation stage. With 40 mW of diode laser power and 230 mW of Yag power the system generates about 6 μW of infrared.

A number of techniques were evaluated for the methane spectroscopy and high sensitivity detection. These include: direct absorption in a single pass configuration, FM derivative spectroscopy, Fabry-Perot cavity-enhancement of the 3 μm radiation, and active noise suppression of the 3 μm power by using an AO-modulator in the diode laser beam. Each of these systems has advantages and disadvantages but all of them demonstrated very good detection sensitivities for methane. Figure 2 shows example spectra of methane taken with the derivative method for three different methane concentration levels in air. These data were taken at a sample pressure of about 100 Torr in a single pass through a 59 cm sample cell. Our best results so far have been with direct detection and active noise suppression, and resulted in an excellent noise-limited detection sensitivity of approximately 20 ppb*m/$\sqrt{}$Hz.

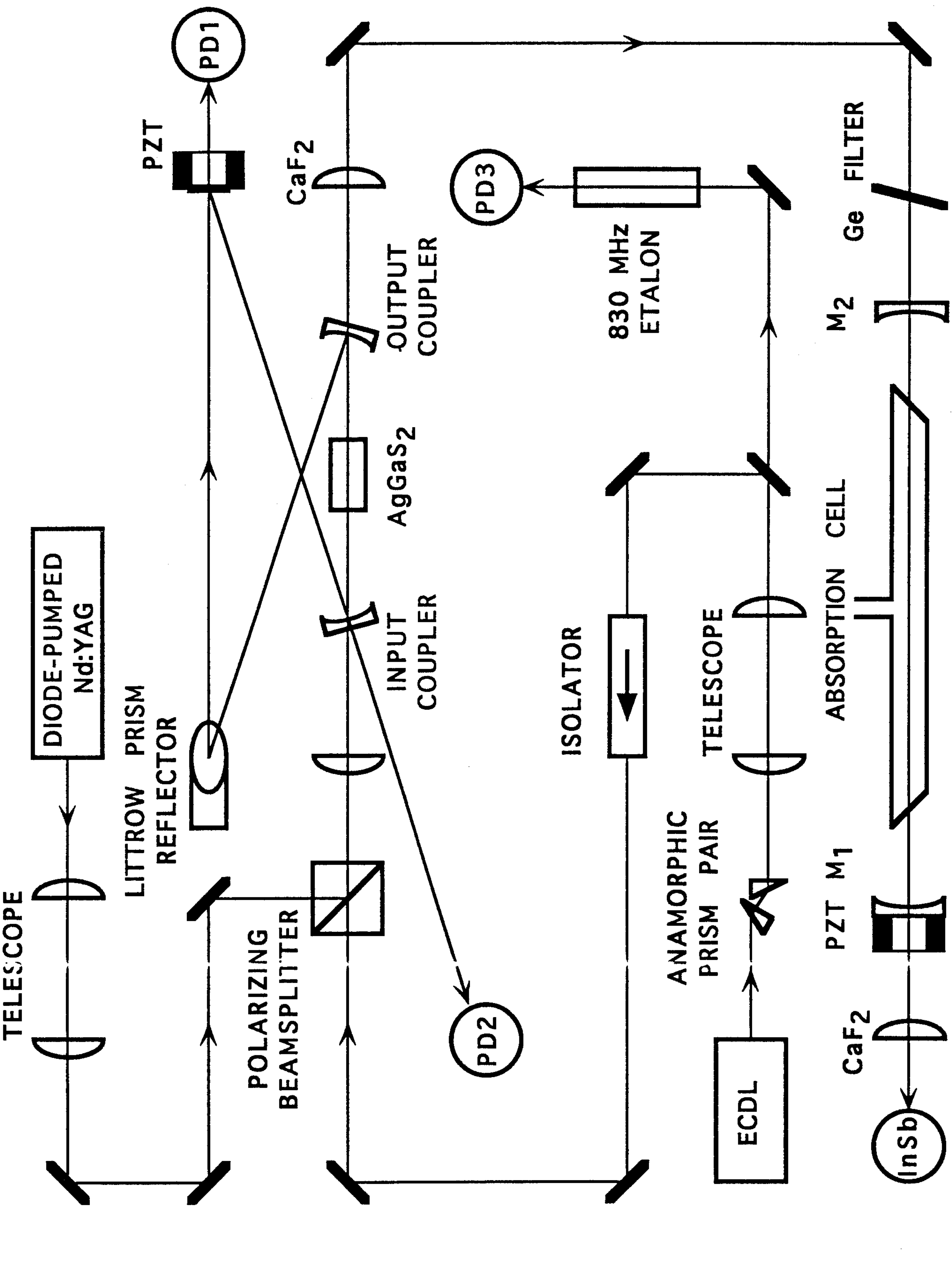
DIODE-PUMPED
Nd:YAG
TELESCOPE
LITTROW PRISM
REFLECTOR
PZT
PD1
POLARIZING
BEAMSPLITTER
PD2
INPUT
COUPLER
AgGaS2
OUTPUT
COUPLER
CaF2
PD3
830 MHz
ETALON
ISOLATOR
ECDL
ANAMORPHIC
PRISM PAIR
TELESCOPE
ABSORPTION CELL
PZT M1
M2
Ge FILTER
CaF2
InSb

Figure 1

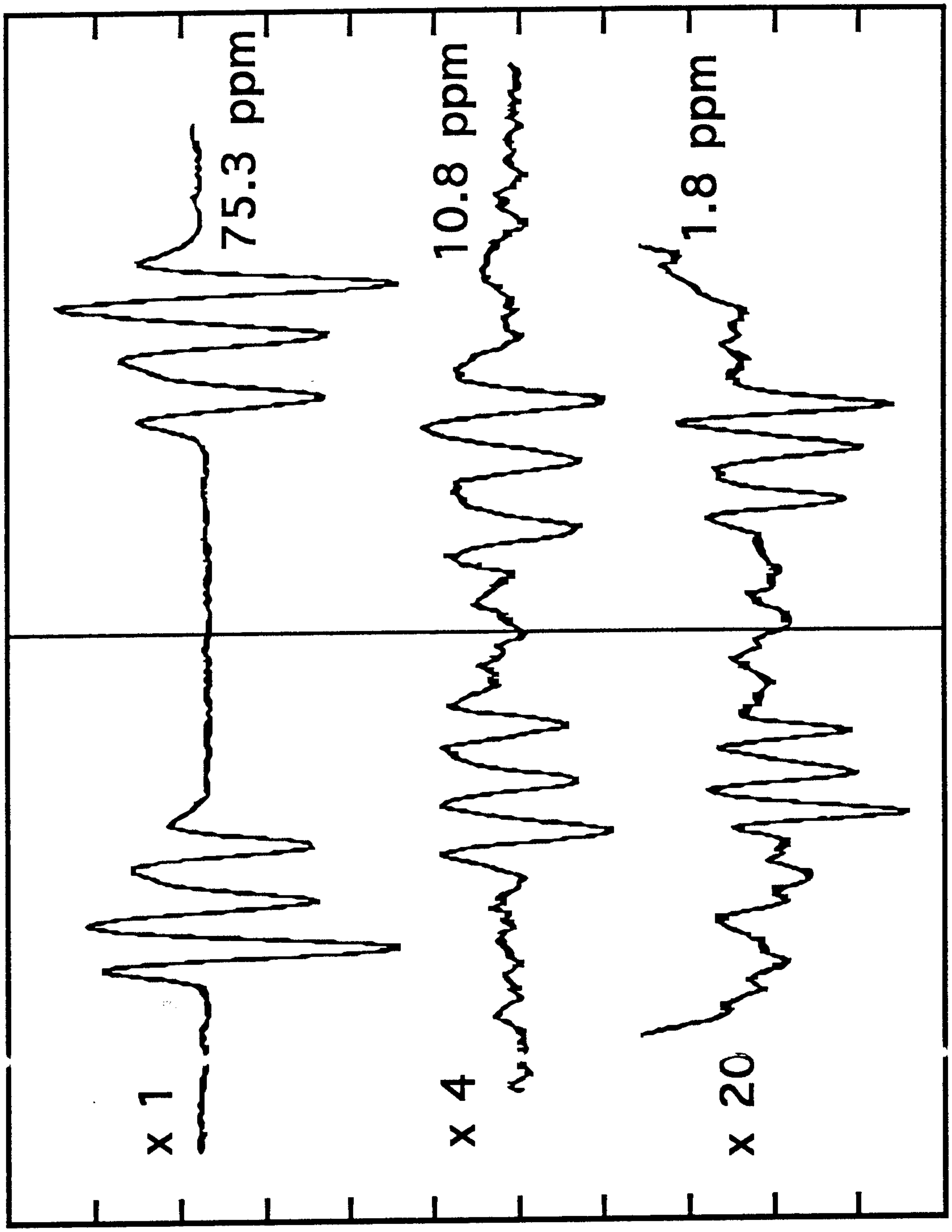

Figure 2