JET PROPULSION LABORATORY **INTEROFFICE MEMORANDUM**

March 5, 1996
Memo DCR-96-05

To: Lisa Sievers (CIT)

Copies: Laura Needels

From: David Redding

Subject: Completion of reduced frequency-resolution recycled interferometer simulation

The reduced frequency-resolution version of the LIGO recycled interferometer (IFO) length-control simulation has been completed and is in the process of validation. This code uses the "short cavity" approximation, involving static solution for the fields in the recycling cavity while solving for the time response of the fields in the longer arm cavities. The result is much-reduced CPU requirements compared to the full frequency-resolution simulation. Temporal resolution for results shown here is on the order of the 1-way light time in the arm cavities (13 usec). As was demonstrated in previous work on the coupled-cavity IFO, this resolution is adequate for control studies with closed-loop bandwidths of about 10 kHz. Resolution can be increased up to 1 MHz using the reduced-resolution code, by changing a single parameter. The simulation runs at better than 50:1 sim/real time for the results shown here.

The interferometer layout used in the simulation is sketched in Figure 1. The code is set up to run any set of parameters within the basic layout. Transmissivity and loss of each mirror, modulation frequency, phase and depth, cavity lengths, asymmetry length, and other parameters can be set. The code can be run in simulation mode or in sine-sweep mode. The latter is used to develop transfer functions.

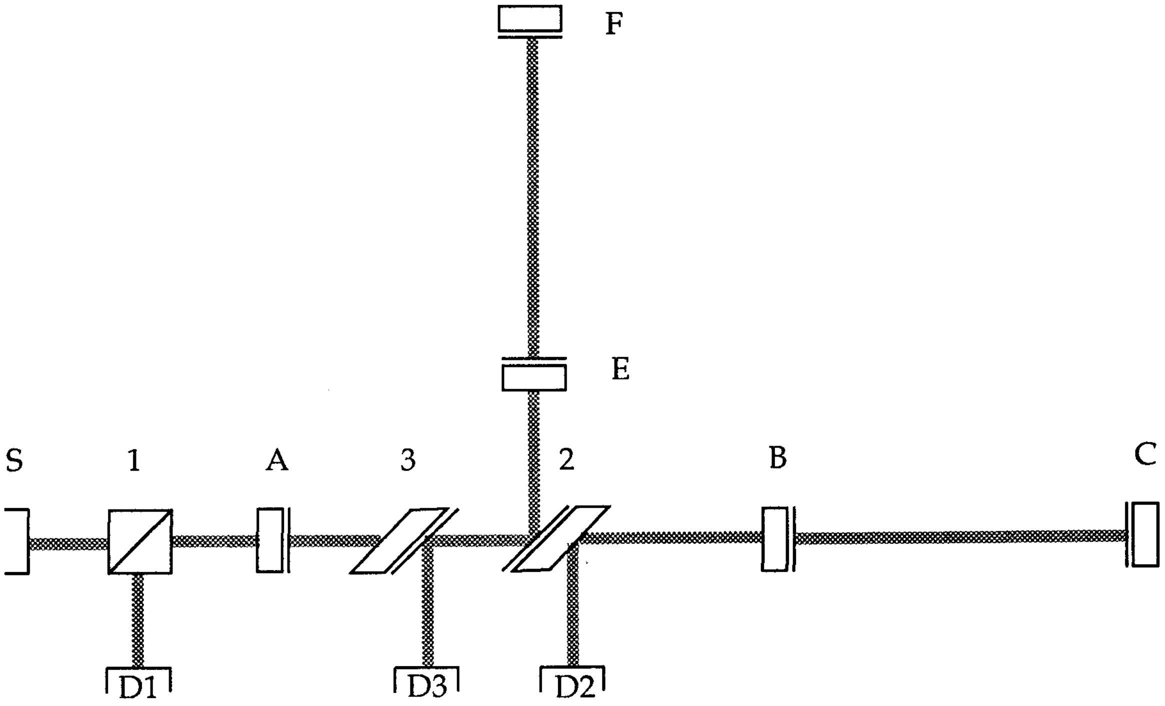

Figure 1. Recycled interferometer configuration and nomenclature.

Controllers are provided for each of the mirrors and the source, plus common-mode, difference-mode and cavity-difference mode (where B and C move in together, while E and F move out together). Any of the signals (quad or in-phase from any of the detectors) can drive any of the controllers. Controller dynamics are specified by S-(system) matrix inputs as in previous simulations. LIGO stack dynamics are used in any run with a controller active.

The simulation files are located in directory ~redding/ligo/y3. The main program is ryRunL.m; cavity parameters are set in rySetCavity.m. ryRunStatic.m runs in static mode only.

Static-mode (DC) response of the simulation has been validated by comparing results with previously validated coupled-cavity IFO and recombined IFO simulations. These simpler configurations are created in the current simulation by setting the transmissivity of particular mirrors to 0 or 1. For instance, coupled cavities are created by setting the transmissivity of beamsplitter 2 to 0 or to 1. This testing involved all controlled DOFs (except the source phase DOF), effects of length asymmetry, effect of demodulation signal phase, and all sensor outputs. A full set of plots documenting the comparison has been provided under separate cover. Results agree to 9 significant figures in all cases.

Validation of the dynamic response will be by comparison of frequency response to Twiddle program results. This will be completed shortly.

Figures 2- 6 illustrate a typical fringe sweep for a LIGO set of parameters (4 km cavities, $\lambda/50$ initial velocity, 95% recycling mirror, 97% front mirrors, 100 ppm back mirrors). In this example, mirror C coasts through a fringe with fixed velocity under no control (see Figure 2). Dynamic response is shown as a solid line, static response by the dashed line in the remainder of the plots.

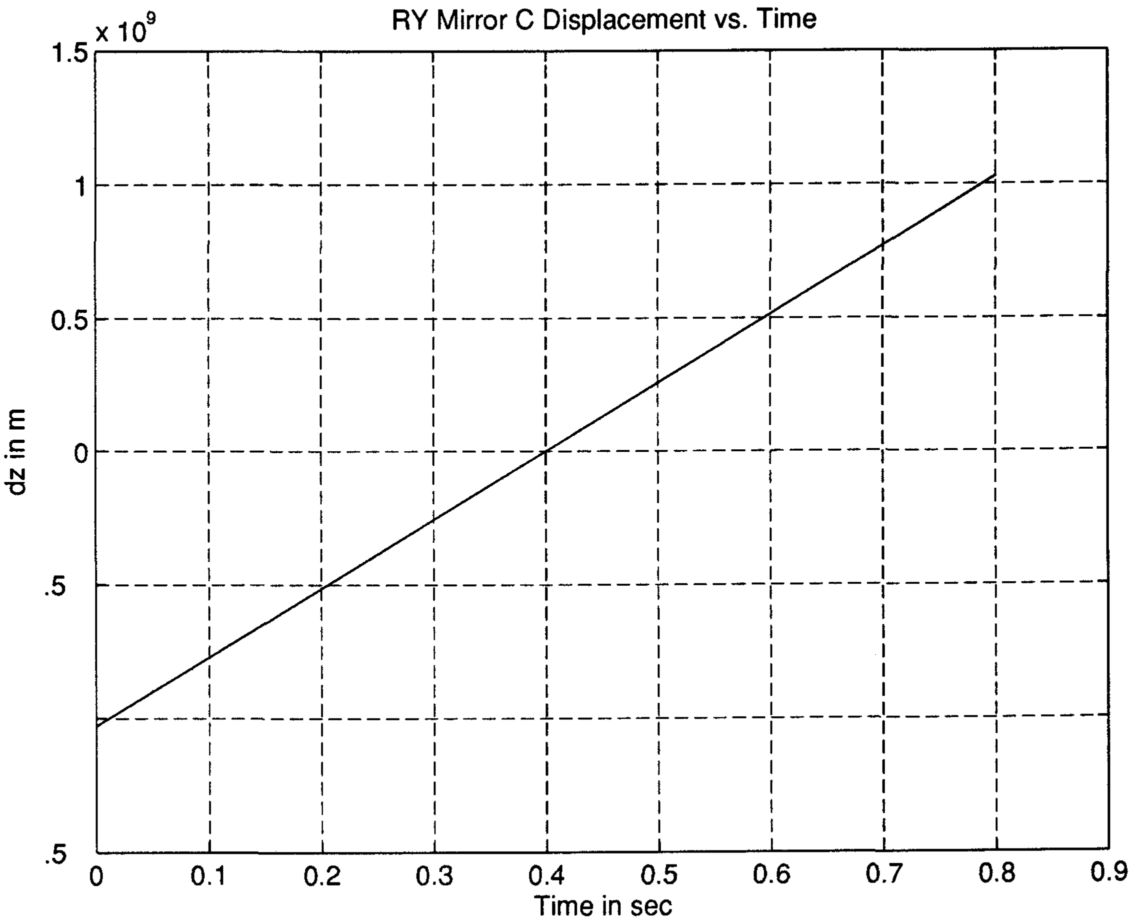

Figure 2. Transient response example: Mirror motion.

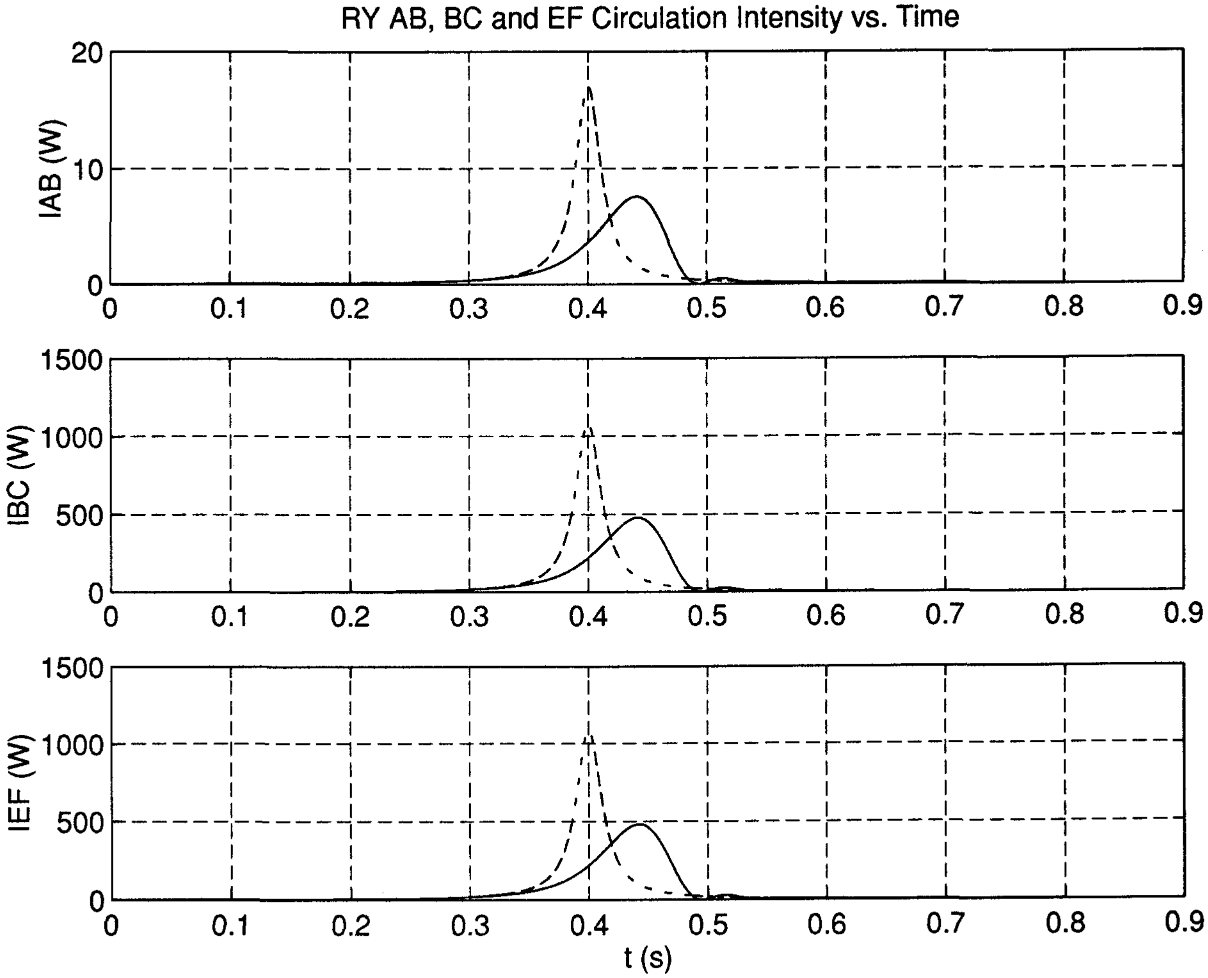

Figure 3. Cavity Circulating Field Intensities. IAB is the intensity in the recycling cavity while IBC and IEF are the intensities in the arm cavities.

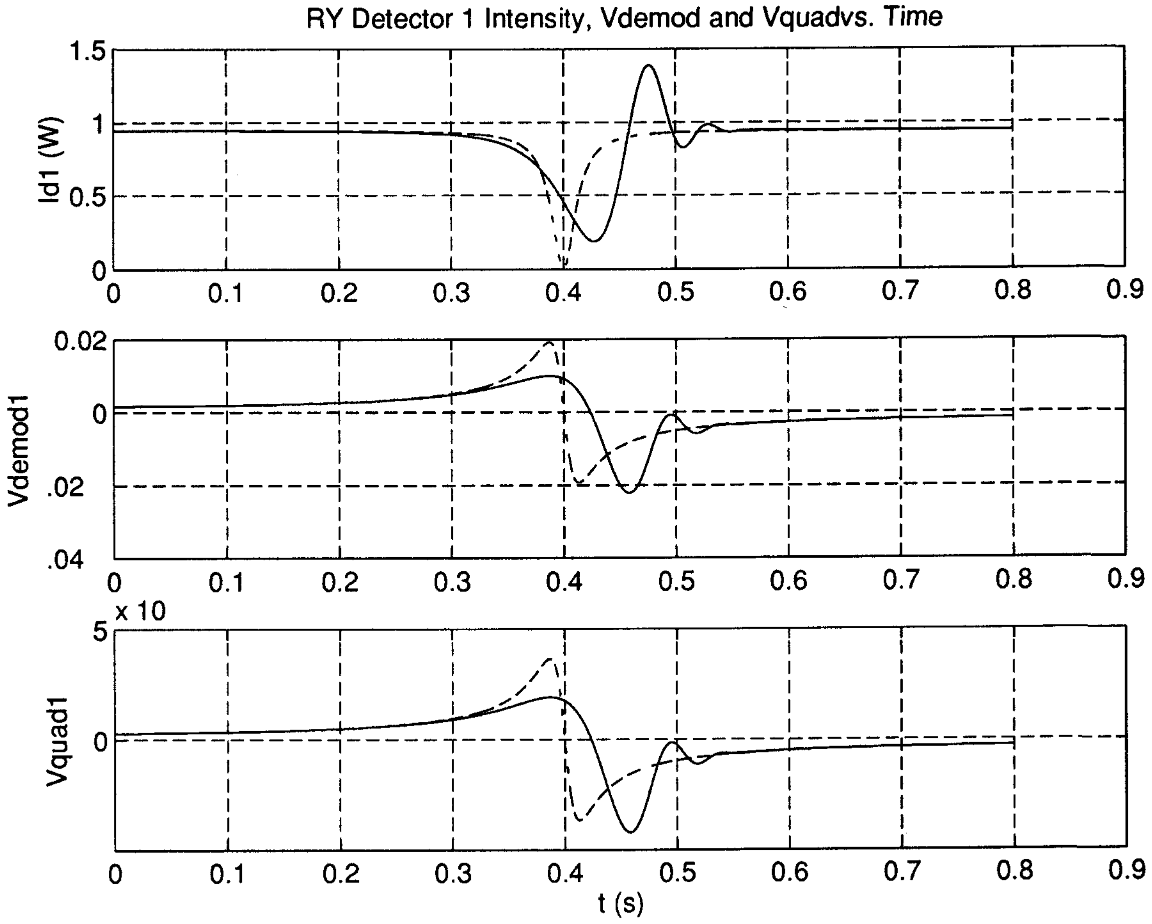

Figure 4. Transient response example: Detector 1 fields and signals. ID1 is the intensity of the light on detector 1 while Vdemod1 and Vquad1 are the in-phase and quadrature-phase demodulated outputs at detector 1.

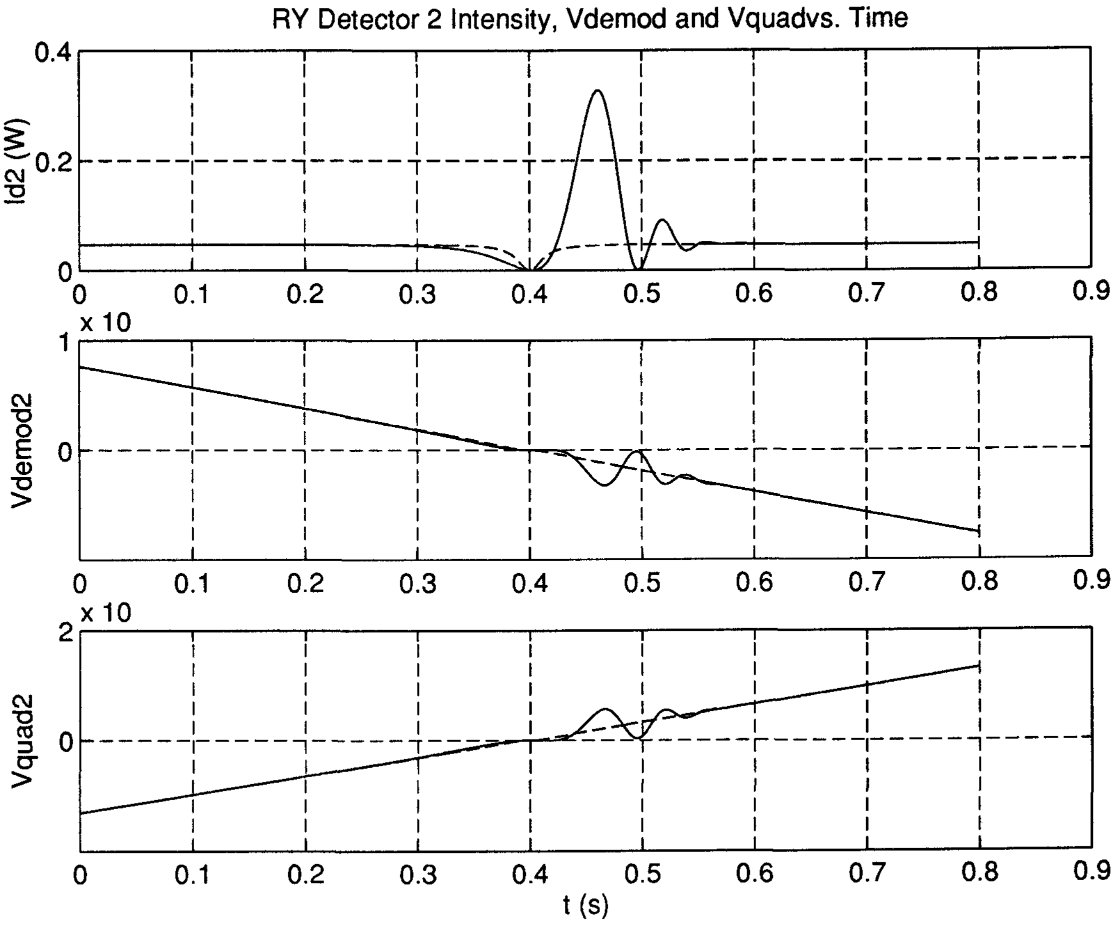

Figure 5. Transient response example: Detector 2 fields and signals. ID2 is the intensity of the light on detector 2 while Vdemod2 and Vquad2 are the in-phase and quadrature-phase demodulated outputs at detector 2.

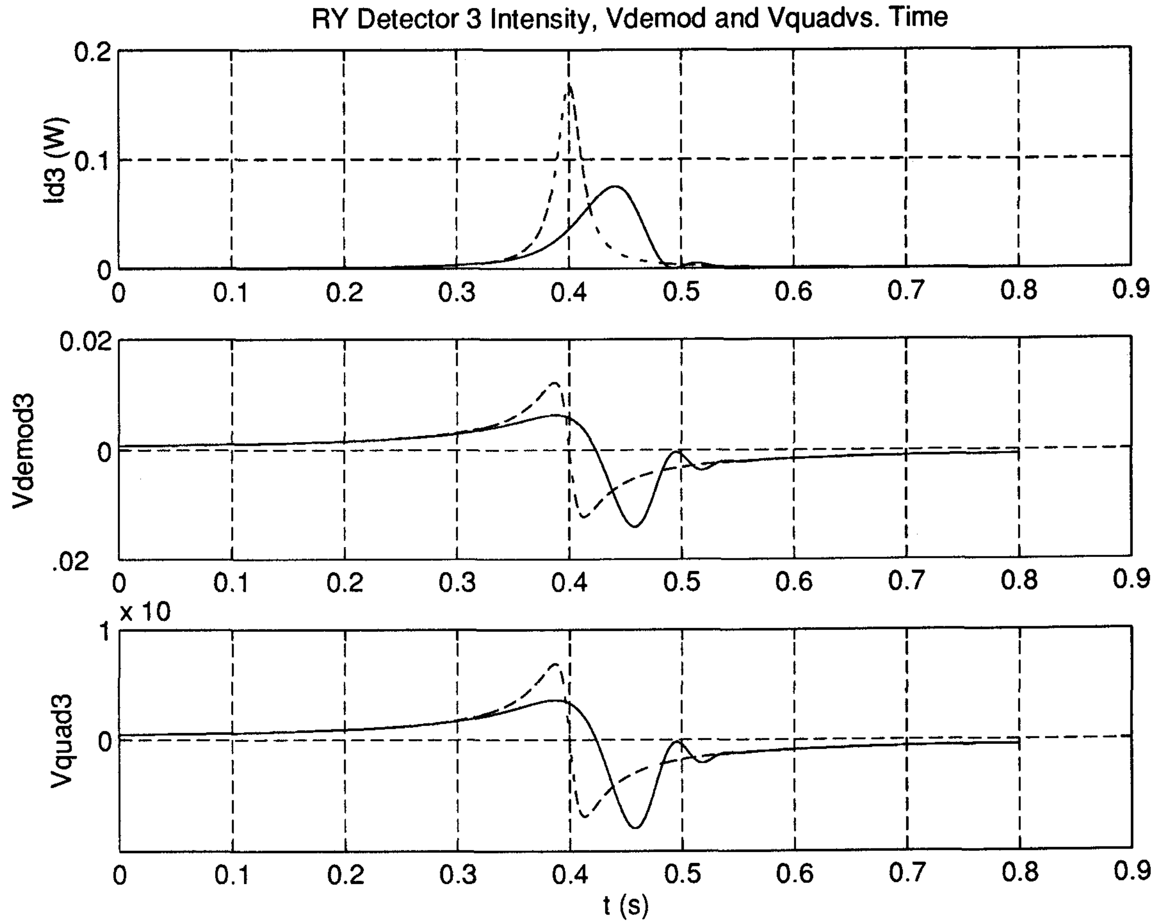

Figure 6. Transient response example: Detector 3 fields and signals. ID3 is the intensity of the light on detector 3while Vdemod3 and Vquad3 are the in-phase and quadrature-phase demodulated outputs of detector 3.