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APPLICATIONS FOR 220 SERIES CHOPPERS

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The ITHACO 220 Series Light Beam Choppers have been designed specifically for a wide range of low–level, electro–optical applications with lock–in amplifiers, photon counters and other signal processing instrumentation. A high speed and low speed drive motor unit and 8 interchangeable blades cover a frequency range from 0.1 Hz to 6 kHz. The blades are precisely photoetched from spring steel stock and are immune to warping if flexed during handling. The basic Model 220 Controller unit yields ultra–low phase jitter. Two other controller units feature additional capabilities. Model 221 provides phase–locked "electrical shaft" operation of two heads to synchronize and phase adjust chopping at separate points in the beam paths. Model 222 allows precise linear sweeping of the chopping frequency.

The eight applications below show techniques for taking advantage of the unique features of the 220 Choppers, Lock–In Amplifiers and Computer Interfacing equipment to solve typical optical measurement problems.

SINGLE BEAM TRANSMISSION, ABSORPTION, REFLECTION MEASUREMENTS

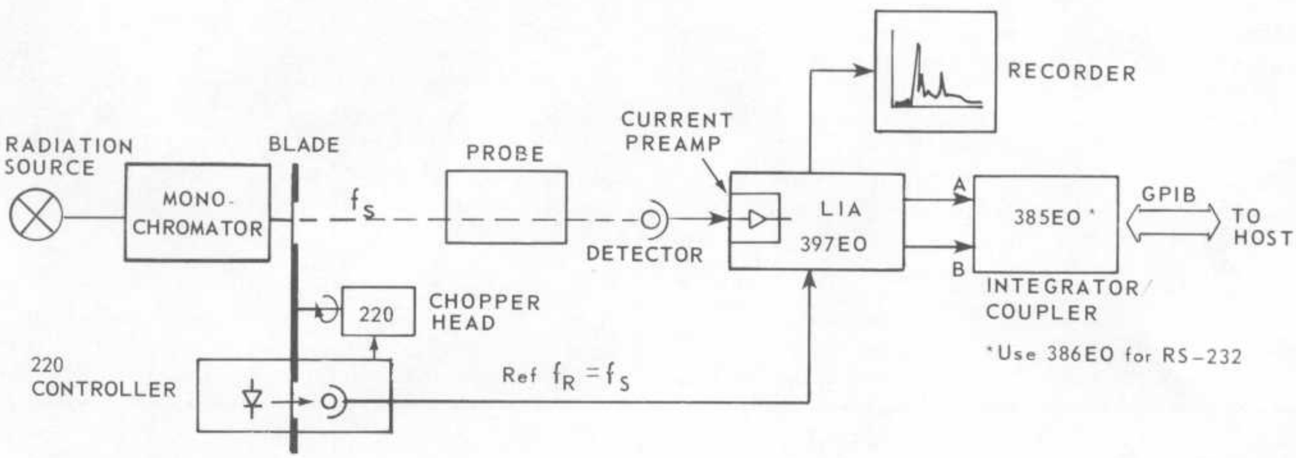

Figure 1 BASIC OPTICAL CHOPPER SYSTEM

A single row blade modulates the light beam (IR to UV) with a frequency f_S. The chopper reference signal synchronizes the Lock–In Amplifier which allows a very stable, low bandwidth, high gain amplification of the modulated signal using a DYNATRAC® Lock–In Amplifier. This leads to noise, interference and drift errors orders of magnitude lower than that obtainable using a high gain DC amplifier system. The setup can work under ambient light conditions if care is taken to prevent ambient light from being modulated by the chopper and falling on the detector. The choice of the modulation frequency is dependent upon the bandwidth of the photo detector. Far IR–detectors requiring lower modulation frequencies than the PIN–Diodes or PM–Tubes used for near IR to UV work. With the exception of a few special cases, 10 Hz to 1 kHz will suffice for most applications.

The accuracy and resolution of the system is limited mainly by the long term instability of the light source in use. In general, errors of less than 0.1% may be expected at detector current levels of approximately 10^{-5} to 10^{-6} Amps or above. The DYNATRAC 397EO is often the best choice for a Lock–In Amplifier for optical work due to its special features such as switch selectable current or voltage input, continuously variable gain, phase independence (dual phase Lock–In) and direct % of readout.

Computer–control can be attained with the addition of the 385EO (GPIB) or 386EO (RS–232) Integrator/Coupler. This special computer interface design offers the benefits of high dynamic range A/D conversion and digital integration (i.e., filtering) without the burden of switching transients, which other systems cannot eliminate.

DOUBLE BEAM SYSTEM WITH DUAL–ROW BLADE FOR PRECISION LOW TRANSMISSION, REFLECTION MEASUREMENTS

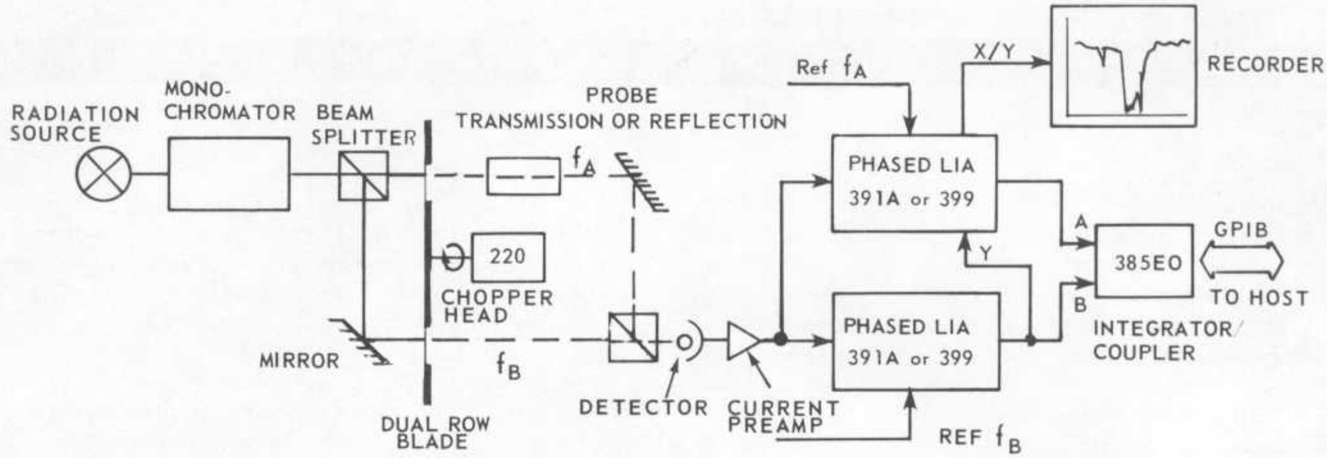

Figure 2 HIGH ATTENUATION DUAL BEAM SETUP

Double beam systems use the signal of a 2nd reference beam generated by a beam splitter as the denominator in an electronic X/Y ratio measurement. This method eliminates the measurement errors due to radiation source instabilities as well as detector instabilities. For very high accuracy requirements (up to 10^{-6}) a symmetrical optical setup is required. The dual row blade on the 220 Chopper modulates the probe path and reference path at different frequencies. Two Lock–In Amplifiers detect these signals separately. X/Y computation can be done by the Analog Ratio Option 02. In this case, it is important that both Lock–Ins are set to the same integration time value (TC) for best short term instability suppression.

If computerized operation via the 385EO or 386EO Integrator/Coupler is used, the Coupler does the X/Y computation with the integration time (amount of filtering) set automatically the same for both inputs. Assuming that the LIA time constants are equal or are set much shorter than the Coupler integration time (e.g., 1/50th the time), short term instability will be adequately suppressed due to balanced filtering in both the signal and reference paths.

This dual frequency setup is recommended for low transmission or small transmission–differences, because the absolute accuracy increases the smaller the probe path signal is compared to the reference path signal. For instance, a 1000 times higher gain for the probe path signal compared to the reference path leads to a 0.1% measurement range and an absolute accuracy of better $\pm 10^{-5}$.

The system is capable of working at very low intensity levels down to 10^{-12}A detector current (depending upon detector). Ambient light can be tolerated as long as the dynamic range of the detector is large and highly linear.

LOW COST DOUBLE BEAM SYSTEMS

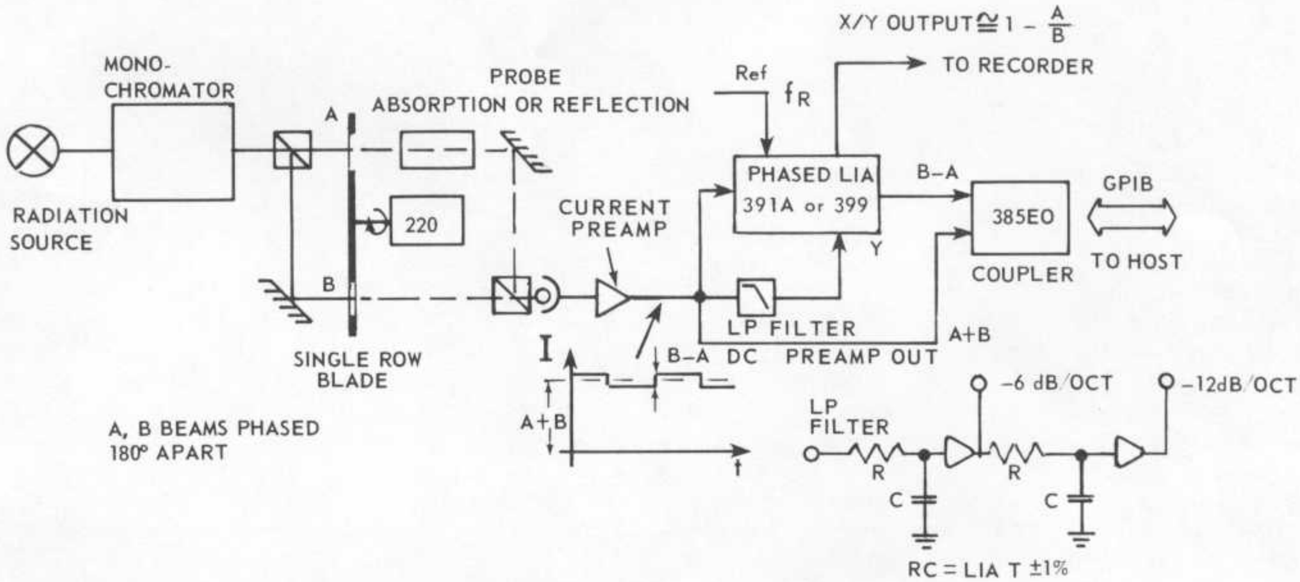

Figure 3A SETUP FOR LOW ABSORPTION OR HIGH REFLECTION

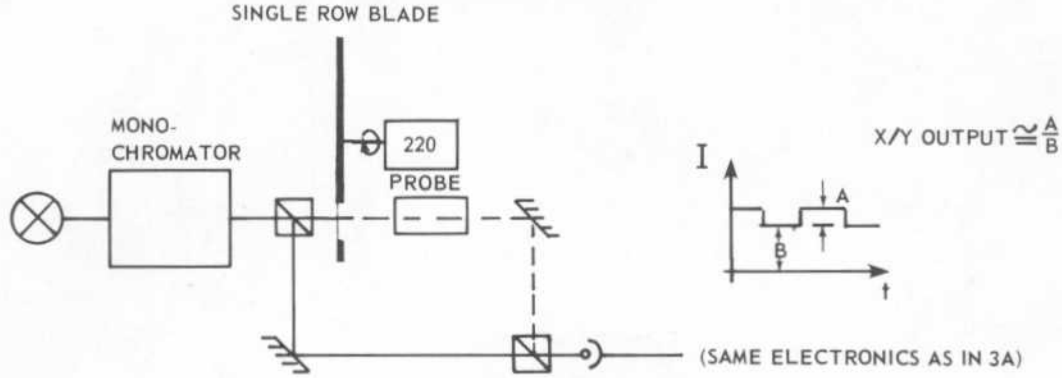

Figure 3B SETUP FOR LOW TRANSMISSION

These setups make use of the DC component of the detector output, which is amplified along with the AC signal in the current preamplifier ahead of the 391A or 399 LIA. This method will work down to approximately a 10^{-5}A reference path DC current. When used without the Integrator/Coupler but instead with the analog X/Y Ratio Option 02, an additional LP filter is required to impose a transfer function on the reference signal identical to the function imposed on the probe path signal by the time constant setting of the Lock–In. If the Integrator/Coupler computes the ratio, it is assumed that the 385/386 dominates the system bandwidth (i.e., the coupler integration time >50 x LIA time constant). These measures to achieve balanced filtering result in adequate short term instability suppression.

These low cost configurations can be used in applications with higher beam intensities at moderate DC gain levels. Care must be taken to prevent problems with the ambient light sensitivity of the reference path.

PHOTO ACOUSTIC SPECTROSCOPY (P A S)

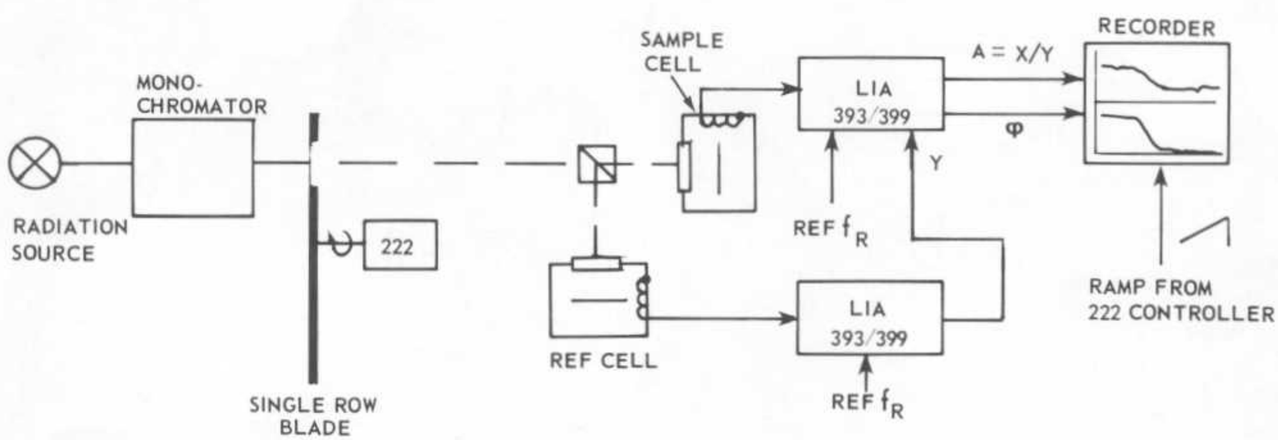

Figure 4 PAS DUAL BEAM SETUP

PAS uses the fact that radiation energy will heat up absorbent probe materials, which if enclosed in a pressure tight housing will cause a pressure increase. The modulation of the radiation source creates a heat wave within the sample cell leading to a pressure wave which can be measured by a microphone. High chopping frequencies show reaction from surface layers only, lower chopping frequencies show higher amplitudes from deeper layers.

The Chopper Model 222 includes a ramp generator for a precision frequency sweep allowing a continuous scan. The signal is detected by a DYNATRAC 393 or 399 2–Phase Lock–In with amplitude and phase outputs. The reference cell and second LIA provide a comparison standard to ratiometrically compensate for error sources. The amplitude/phase correlation allows depth–profiling of fluids or solids when optical spectroscopy fails or requires complicated probe preparation. Both lock–ins must have identical time constants.

LUMINESCENCE DECAY TIME MEASUREMENTS

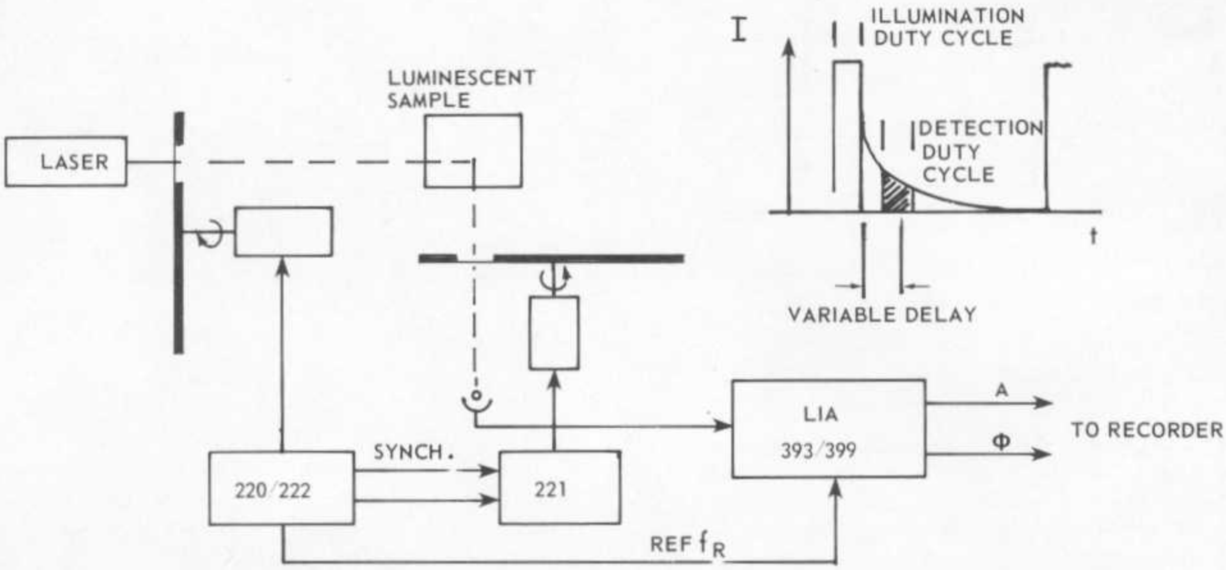

Figure 5 SYNCHRONIZATION TO ACHIEVE TIME DELAY

This setup uses two choppers. The master controller, which may be either a swept frequency model (222) or fixed frequency model (220), modulates the illumination provided by the radiation source. The slave unit (221) is phase synchronized to the master to set the time delay of the detector measurement window by means of its variable phase control. The illumination and detection duty cycles are set by mounting two blades on each chopper head.

ELECTRONIC CONTROL OF APERTURE WIDTH (Pulse Width Control)

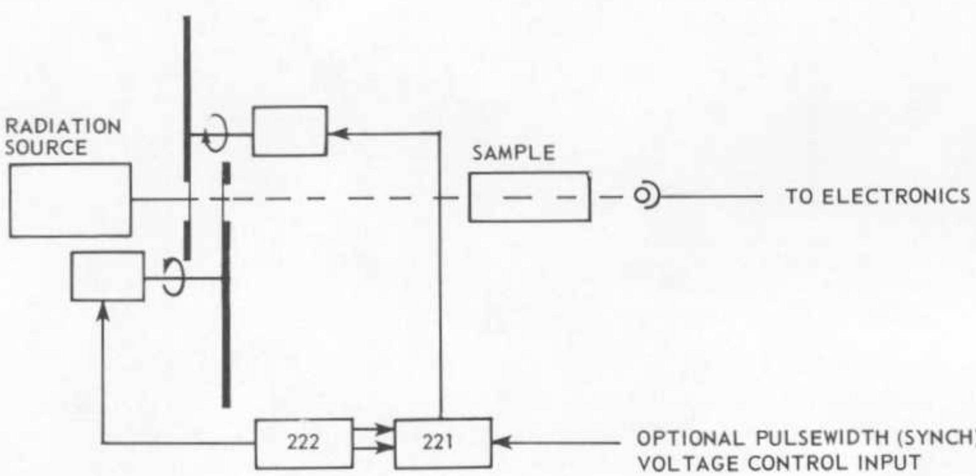

Figure 6 SYNCHRONIZATION TO ACHIEVE VARIABLE DUTY CYCLE

In cases where the pulse duration has to be variable at either a constant or a swept repetition rate, a 220/221 or 222/221 Chopper combination is applicable. The ±100° phase shift of the synchronized 220 Chopper allows an aperture variation from 1/1 to almost zero, even under swept frequency conditions.

HIGH STABILITY CHOPPER REFERENCE

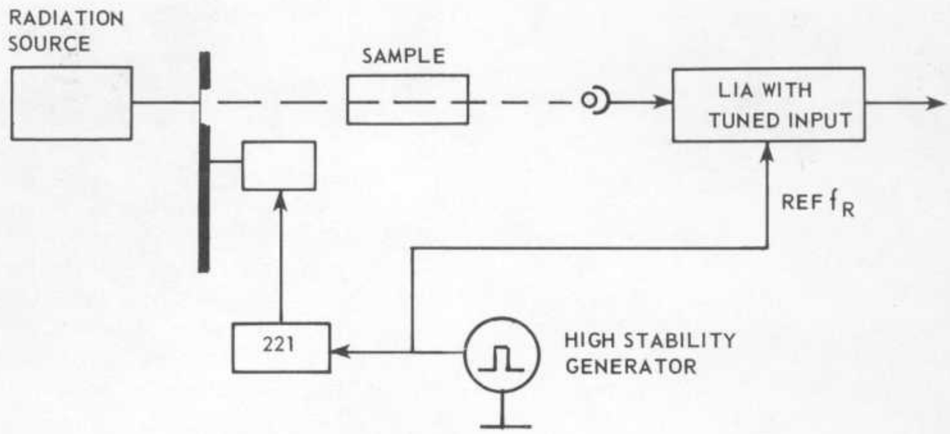

Figure 7 NON–HETERODYNING LIA SETUP

In cases where non–heterodyning Lock–In Amplifiers from other manufacturers are in use, which necessarily must have manually or computer controlled high Q pre-filtering in the signal path, frequency stability is a question of utmost importance. In contrast to their effect upon heterodyning Lock–Ins, very tiny frequency variations will cause large phase and gain errors in these instruments. The above setup uses the Model 221 and the LIA synchronized to the same precision generator leading to a matched long term stability of the two units.

NON LINEAR OPTICS

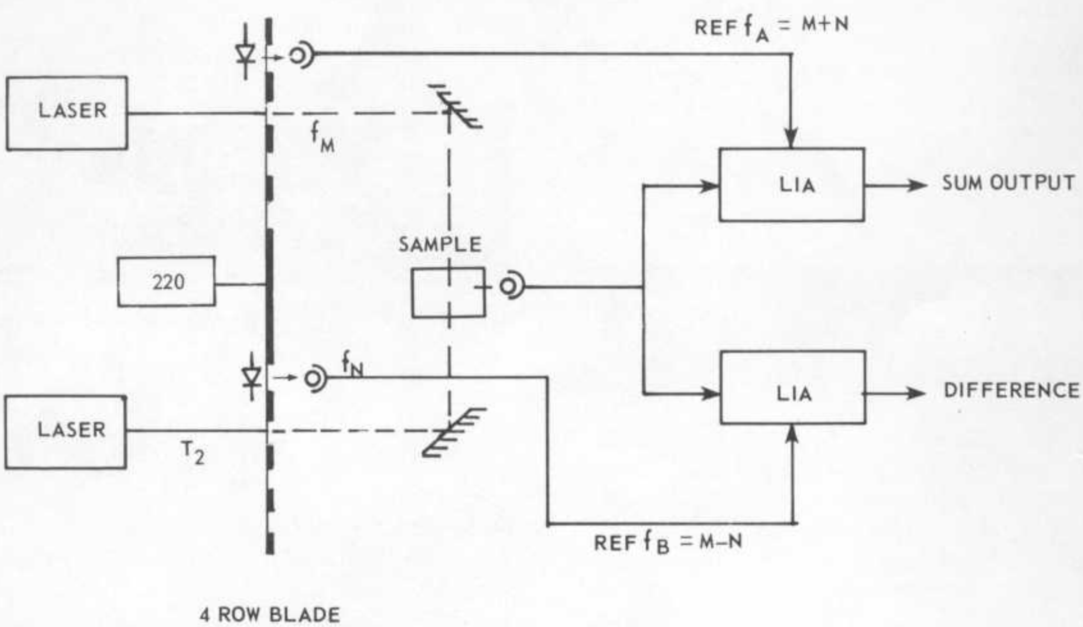

Figure 8 USE OF A QUAD–ROW BLADE

Non–linear optical effects of the probe material show inter–modulation signals, which result in detector output at the sum frequency A=M+N and the difference frequency B=M–N. The 220/7–9–16–25 blade facilitates such measurements with a single chopper. The M+N and M–N reference frequencies are present at the A and B reference outputs (since 16–9 = 7 and 16+9 = 25).