Proceedings of the 2003 IEEE Aerospace Conference, Paper No. 1560

Real-Time 1550 nm Retromodulated Video Link

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Abstract - We report an eye-safe, 1550 nm, retromodulated infrared data link which supports real-time color video. The retromodulated link was 2 meters in the lab and supported 3 Mbps and 30 frames per second using wavelet compression. The device consumes about 75-100 mW and is 10 grams, mounted. We will show a video sequence from the test. We will also discuss future plans for the device.

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1. INTRODUCTION

Free space optical communications and data links in the near-infrared are providing viable solutions to applications where payloads must remain small, lightweight, and draw as little power as possible. Since the carrier is in the Terahertz regime, there are not frequency allocation conflicts, greatly alleviating present problems with channel crowding and interference experienced by Radio Frequency (RF) links.

Although conventional one-way laser communications serves the community well in terms of exploitable bandwidth and reduced power, size, and weight compared to RF, retroreflected links are being shown to offer especially compact, low power solutions for niche applications [1.2].

Modulating retro-reflector systems using Multiple Quantum Well (MQW) technology are being shown to provide a low power, low weight, multi-functional solution which can support up to tens of Mega bits per second (Mbps) over kilometer-class ranges [3]. New architectures are under development that promise hundreds of Mbps as well [4].

A retroreflected free space communications link differs from typical RF and standard laser communications link in that the retromodulator with its encoding circuitry and nominal power source can be the entire communications terminal at the data collection site.

Essentially, an optical retroreflector is coupled with an electro-absorptive "shutter" which modulates incident light and returns an On-Off signal directly to the interrogator along line-of-sight. A remotely located laser interrogates the MRR,. The digitized stream modulates the MQW shutter. The modulated return light is reflected along line-of-interrogation and the received signal demodulated. The receiver would provide data recovery, video reconstruction, photonics, and communications channel characterization (e.g. bit error rate). A concept is shown in Figure 1.

The Naval Research Laboratory (NRL) has been investing in the development of MQW devices which operate at 1550 nm in addition to those which operate from 850 nm to 1.06 microns [5]. The 1550 nm devices provide a means to establish eyesafe links that are robust through the atmosphere.

In this paper, we describe what we believe is the first implementation of such a device supporting real-time color video at 30 frames per second at 5 Mbps. The link was demonstrated in the laboratory over 2 meters and used wavelet compression to encode the NTSC formatted data.

2. 1550 NM MQW RETROMODULATOR

Multiple Quantum Well modulators fabricated for free space communications have several advantages. These types of modulators have very high intrinsic switching times (greater than 10 GHz), and in practice are limited in their modulation rate only by RC time. A fabricated device suitable for larger apertures (centimeter-class) can operate at tens of milliwatts and be configured in single units the size of a quarter, or if configured into an effective array, the size of a softball.

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**
4. TITLE AND SUBTITLE **Real-Time 1550 nm Retromodulated Video Link**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,4555 Overlook Avenue, SW,Washington,DC,20375**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

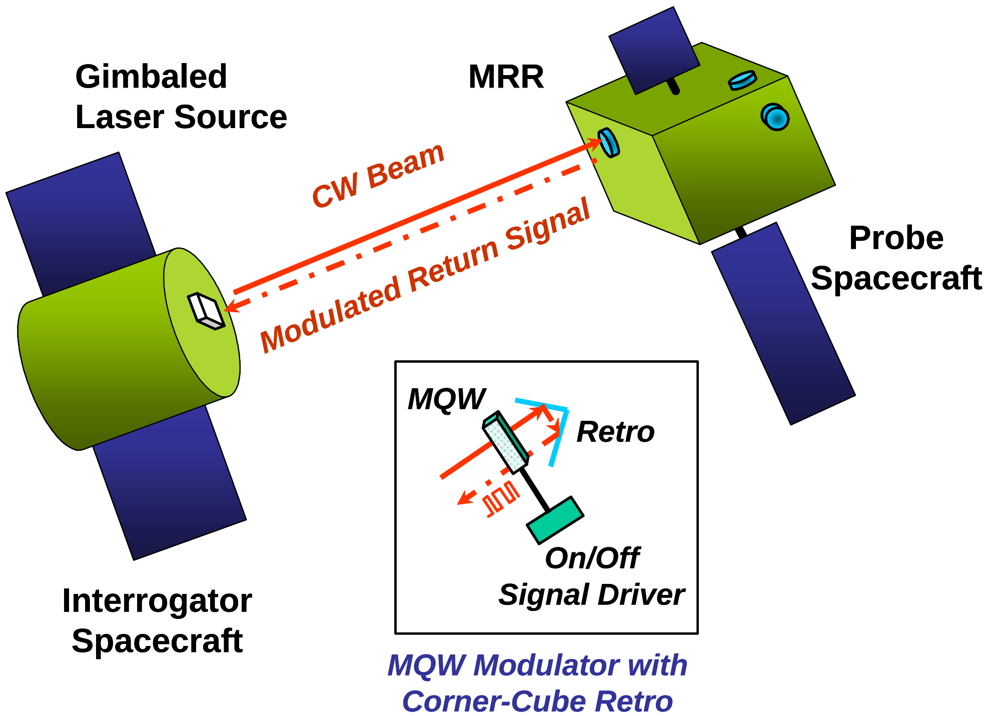

Figure 1. Concept for Modulating Retroreflector: A laser Transmit/Receive Communications Terminal is integrated on the Interrogator spacecraft. The laser illuminates the MRR target on the Probe spacecraft. The MRR is encoded with data from the onboard sensor and the retroreflected light is modulated and received by the Interrogator.

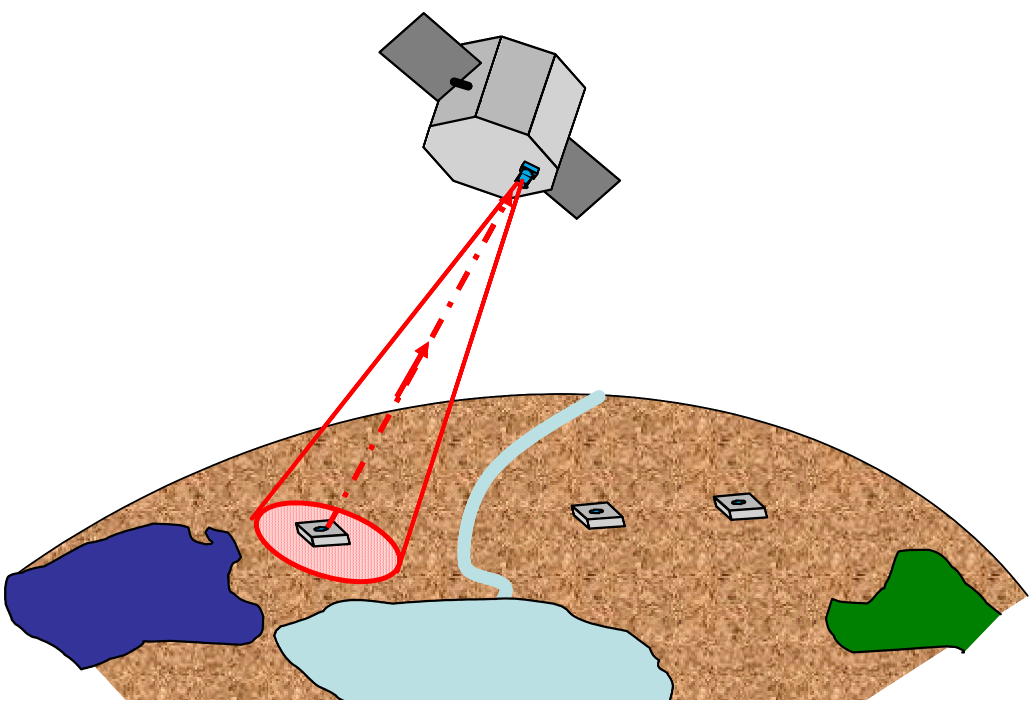

Figure 2. Concept for Modulating Retroreflector: In this scenario, the MRR is situated on the planet surface with a sensor. The unit is interrogated by a low orbiting vehicle to obtain data remotely.

To make the devices more useful in a terrestrial regime where eye safety and transmission through the atmosphere are issues, we have begun to develop devices which operate at 1550 nm. These devices are based on quantum wells grown on InP wafers. A detailed description can be found elsewhere in these Proceedings [6].

Previous MQW modulators developed at NRL for free space optical data transfer were based on low Indium content using InGaAs/AlGaAs grown on GaAs. These devices were suitable for comunications in the 850 nm through 1.06 nm regime. However, the 1550 nm regime dictated developing a new family of devices on InP [4]. Because of the large capacitance of the devices and the high sheet resistance of the p-doped layer, a special electrode structure was designed and used. This structure reduced the effective resistance of the p-doped layer and improved the overall frequency response of the device by nearly an order of magnitude of the simple ring contact architecture. This mask is shown in Figure 2.The device itself was not segmented.

3. EXPERIMENTAL CONFIGURATION

In this experiment, a Sony Camcorder was connected to an L3 wavelet compression unit using a standard NTSC interface. The camcorder was mobile but linked via cable to the drivers. The output was then sent through an impedance matching circuit to drive one of the 1550 nm retromodulators. This "payload" was then placed approximately 2 meters from the laser transmitter/receiver interrogator on an optical bench in a laboratory environment. The incident light from a 1550 nm fiber coupled laser diode was directed through collimating optics to present a 1 centimeter beam at the MRR. Approximately 100 microwatts was incident on the device and data transfer occurred at completely eye safe light levels.

A 0.63-cm diameter InGaAs/InAlAs modulator was used in this demonstration. The modulator was designed for transmissive operation. It was fabricated with a center frequency of 1550 nm and bandwidth of approximately 10 nm. It was mounted in front of a 0.63 cm corner cube retroreflector, which was anti-reflection coated at 1550 nm and had a protected silver coating on the reflecting surfaces.

The unit was integrated into our standard experimental mount which enables us to swap out the modulators. The mounted unit is 10 grams, measures about two centimeters in diameter, and presents a 30-degree FWHM field-of-view. A photo of the mounted device is shown in Figure 3. The modulator was driven with 15V to provide a contrast ratio of about 2.2:1.

The form factor for the compression unit is small - on the order of 8cmx3cmx10cm. The mounted retromodulator measures about 2.5 cm on a side for a unit. The modulator itself required 80 to 130 mW to drive the link. The compression unit required 9W, which dominated the power draw requirement.

The light was directed through a monostatic configuration whereby the outgoing and incoming light had the same optic axis. Aperture sharing was accomplished with a beamsplitter. A wideband PIN-FET served as the relatively low noise detector and had a bandwidth of 12 MHz. A photo of the Transmit and Receive optics is shown in Figure 4. The Transmit/Receive system was separated from the MRR and digitizer on the optics table.

Frame and bit rates were varied to explore image quality. The L3 wavelet compression unit enables error corrective coding. We chose the Reed-Solomon block encoding option for transmission.

4. RESULTS

The device in this bench configuration could support data rates of at least 5 Mbps. A representative data stream for this data rate at 10V is shown in Figure 5. At this flux level, a 3 Mbps link was supported and color video was transferred without significant bit drop-out at 15 to 30 frames per second. Figure 6 shows a still image of the transmission at 3 Mbps at 30 frames per second inside the lab environment. A video clip is to be available on the project's web site [7]. When the beam was blocked, transmission stopped, freezing the frame. Frame recovery was on the order of milliseconds.

A key aspect in this demonstration is the very low power required by the retromodulator unit itself compared to the power requirement of the digitizing component in the communications terminal. This points to a new area for technology investment.

5. SUMMARY AND FUTURE DIRECTIONS

In this paper, we report the first real-time color video transmitted over a 1550 nm retromodulator link. Data rates varied from 1 Mbps to 5 Mbps and the link could support up to 30 frames per second under completely eye safe conditions. The MQW modulator was fabricated using a new electrode design which helped improve frequency response.

The next step for this particular device and configuration is to install an array of these devices on a boat with the camcorder and the video compression unit. We will then test how video can be transmitted over kilometer-level links in a maritime environment. First efforts using 1550 devices were demonstrated to support 5 Mbps data streams over a 1 km link [8]. Incorporating the video is the next step for that testing.

These devices will also be explored for applicability for inter-satellite communications and navigation applications as well as for intra-network applications to replace cables on spacecraft buses

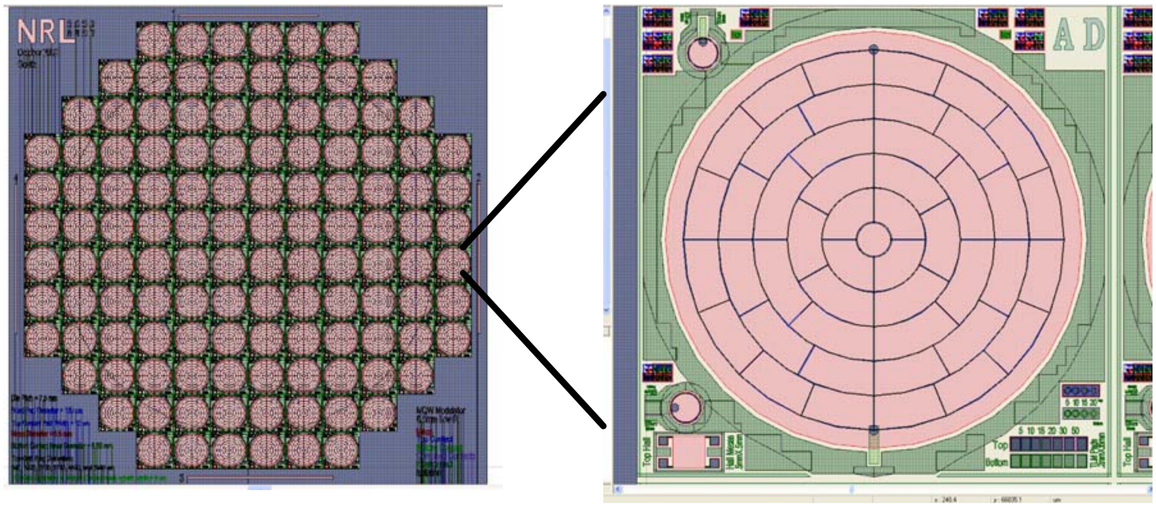

Figure 3. Mask for electrode distribution used in fabricated NRL's MQW retromodulators which operate at 1550 nm. The structure has been shown to increase the frequency response of the larger devices, in particular.

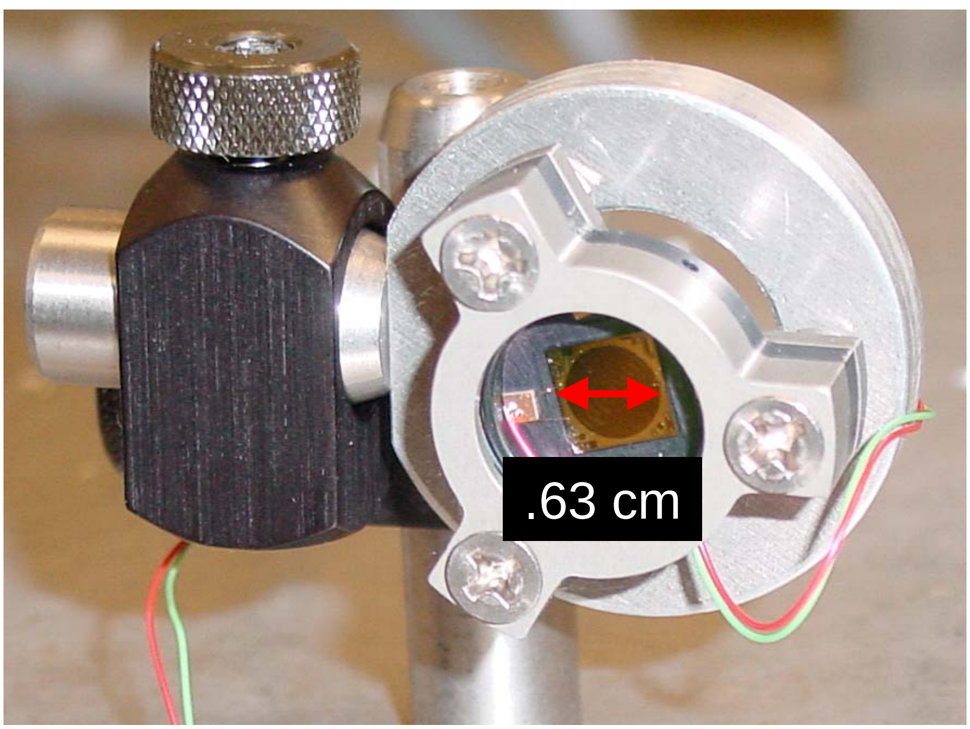

Figure 4. Mounted 1550 nm MQW retromodulator used in demonstration. MQW shutter and retro are aperture-matched. The mount diameter is 2X larger to keep field-of-view as large as possible.

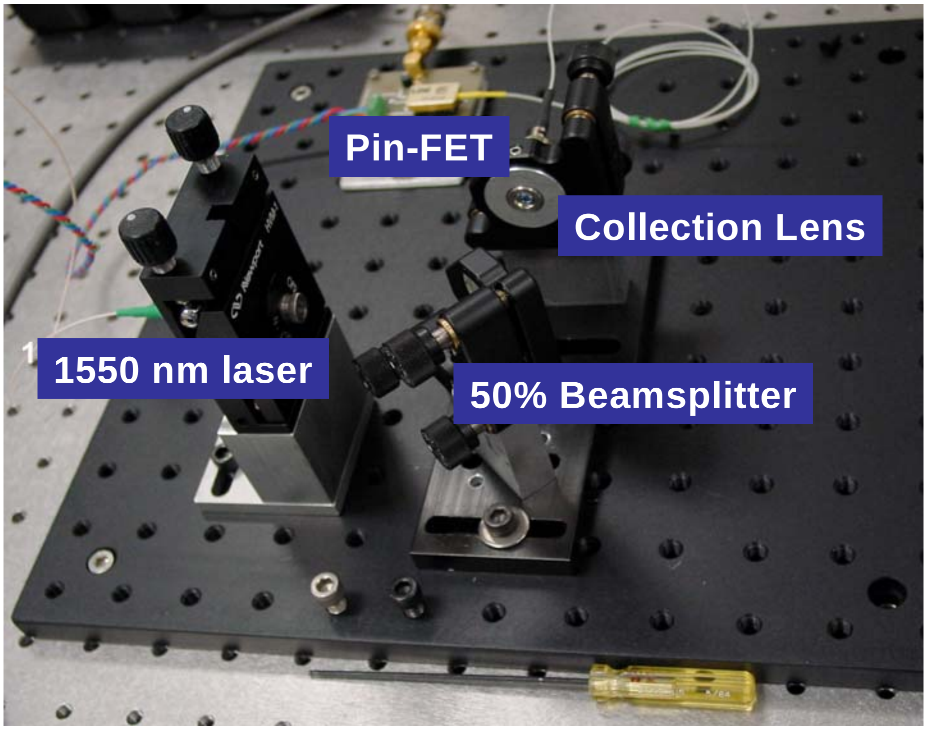

Figure 5. 1550 nm laser with transmitting optics shown above with receiver optics and PIN/FET receiver. The 50% of the transmitted light propagates across a 2 meter range to the MRR. The retroreflected beam is directed to the PIN-FET with the beamsplitter and optics.

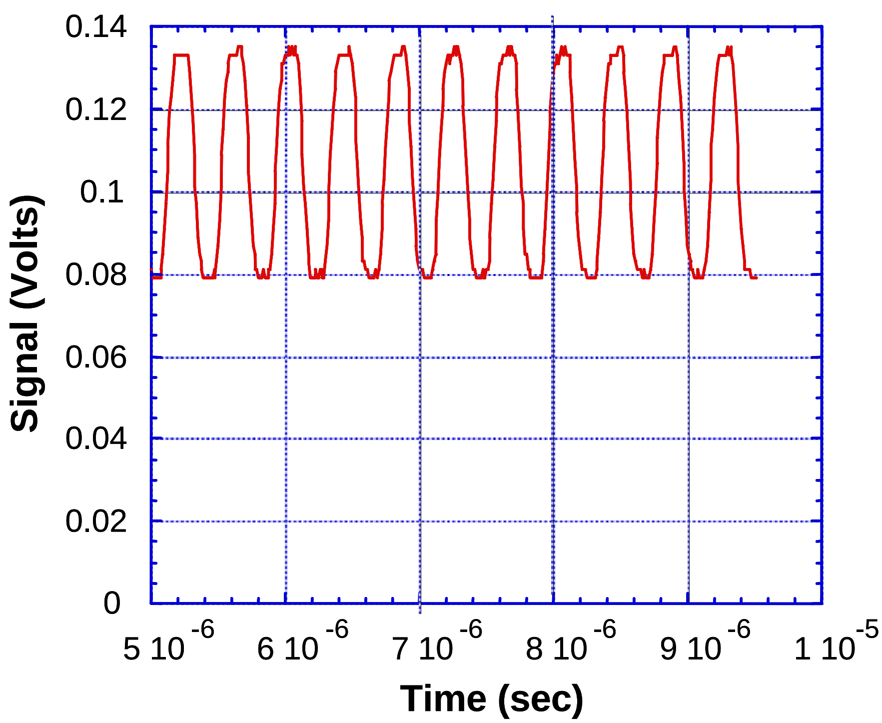

Figure 6. Data stream from 1550 nm 0.63 cm MQW retromodulator. Modulator was driven at 5 Mbps at 10V.

Figure 7. Still from video clip transmitted over 1550 nm MQW retromodulator link. Data was transferred over 2 meters in the lab at 5 Mbps at 30 fps.

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BIOGRAPHIES

Dr. G. Charmaine Gilbreath received her B. S. in Physics from Georgia Institute of Technology in 1982, her MSE in Electrical Engineering and Ph.D. from The Johns Hopkins University in 1986 and 1989, respectively. She has been with the Naval Research Laboratory since 1982. Her specialties are in nonlinear optics, free space optical data transfer, and optical device development. She is the Lead Principal Investigator for NRL's MQW retromodulator programs.

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