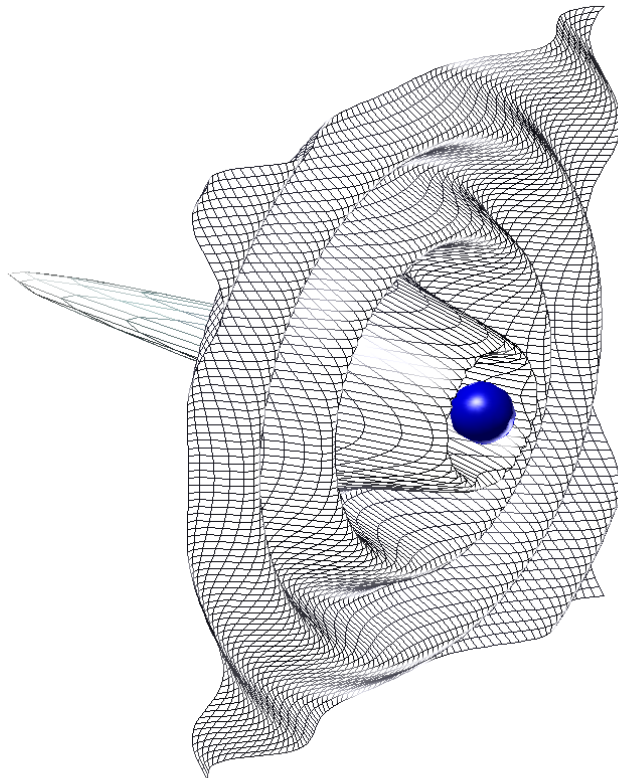# Holodec II Technical Manual

Research Aviation Facility

National Center for Atmospheric Research

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Holodec II

Contents

1 Introduction

1.1 Description

The Holographic Detector for Clouds (HOLODEC) II is an aircraft mounted, holographic, digital cloud imaging system. The instrument uses the technique of digital inline holography to capture the 3D position and outline of particles present within the 20 cm^3 sample volume during the time of exposure. In this fashion it is able to capture discrete, local volumes of cloud particles at a rate of 3.3 Hz.

1.2 Instrument Layout

The Holodec II's chassis is divided into two halves along its length by two aluminum mounting plates. These two halves are labeled as the "laser" and "camera" sides based on the respective mounting locations of the laser and camera. Figure 1.1 shows the instrument from each side with the key components labeled.

The instrument can be divided into four main subsystems:

Sample volume size	20 cm^3
Sample rate	3.3 Hz
Exposure Time	1.6 ns
Size resolution	6 μm to several mm
Mounting Style	Standard PMS style can

Power Distribution The instrument uses both 120VAC and 12VDC to operate its various systems. The main power distribution center is located at the rear of the instrument on the laser side and consists of an array of circuit breakers. The power supply unit for the 12VDC subsystem is located on the camera side of the instrument, midway down the chassis.

Instrument Control The instrument is controlled by a microcontroller based logic board located on the laser side, just forward of the power distribution center. This controller allows for advanced, autonomous control over the instrumet, greatly reducing the amount of required human interaction.

Heaters and Thermal Regulation To ensure all sensitive electronics stay within their designed operating temperatures and to keep the optics fog and ice free, the instrument contains several heated zones, controlled by PID based process controllers located on the camera side of the instrument, directly opposite the power distribution center (aft of the 12VDC power supply).
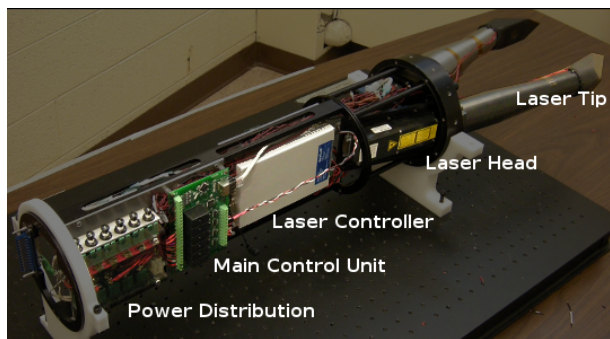
(c) Laser side of instrument
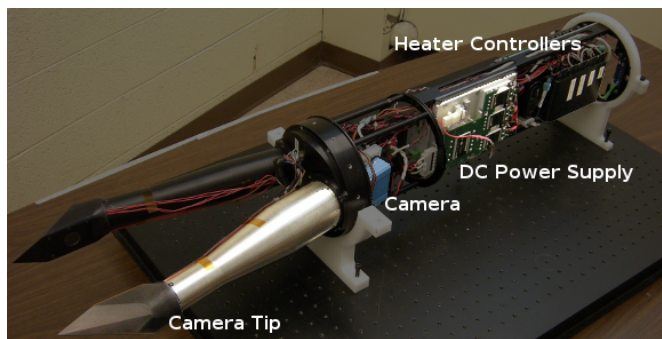
(d) Camera side of instrument

Figure 1.1: Layout of main components

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Optics and Imaging The heart of the system is the optical and imaging systems, which consist of the laser, camera and supporting optics and electronics. The laser head and camera are mounted directly to the front bulkhead on their respective sides, with the laser control hardware mounted to the central mounting plate just behind the laser head (forward of the main control unit). Extending forward from the main chassis are two arms which hold the optics required to form and capture the hologram. At the end of the arms are two heated tips which house the main turning optics.

2 Power Distribution
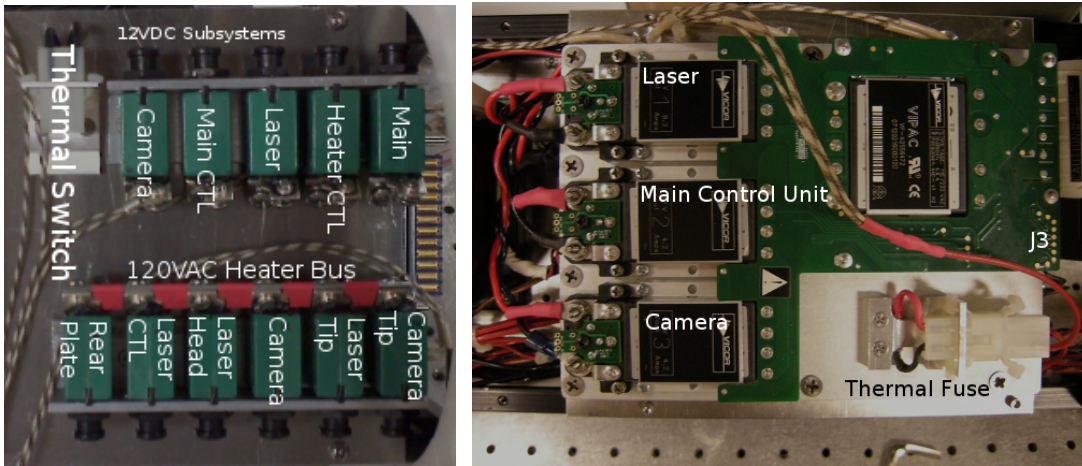
(a) Detail of power distribution center. All breakers along the bottom edge are joined by a common rail and supply power to the heating elements. Left-most three breakers along the top serve the 12VDC subsystems, followed by the 120VAC circuit to the heater controllers and the 10A main breaker. The entire plate is warmed by means of three 30W heaters controlled by a bi-metal switch located in the upper left corner of the figure.

(b) Detail of power supply unit for 12VDC subsystems. Control of individual rail is accomplished through connector J3. PSU and laser controller (on reverse side) are actively heated, with heater power running through a thermal fuse.

Figure 2.1: Details of 120VAC and 12VDC power systems

2.1 120VAC Main Power

120VAC main power is supplied to the instrument through pins 23 and 24 of the Amphenol back plane connector and is fed through a 10A main breaker into the power distribution center illustrated in figure 1(a). 120VAC power is used as supply current to all on board heaters, as well as power for the heater controllers and the power supply unit for the 12VDC subsystems.

WARNING The line terminals and busbar have minimal shielding and present a shock hazard. Use supplied cover to shield power distribution center while instrument is bench mounted.

2.2 12VDC Subsystem Power

The 12VDC subsystems are supplied by a three rail power supply unit shown in figure 1(b). Supply power for the PSU is drawn directly off the 10A main breaker. The PSU has a total capacity of 200W@12VDC, which is divided up amongst three isolated rails. Rail number 1 supplies 100W for the laser, which requires up to 70W during warm up. The second (middle) and third rails are both rated at 50W and supply power to the main control unit and camera (respectively).

Each rail is optically isolated with optoisolators accessible through connector J3. Application of 10 mA@5VDC across pin pairs 1 and 2, 3 and 4, or 5 and 6 disable rails 1, 2 and 3 respectively. This main control board makes use of this feature to control power switching to the laser and camera.

The PSU and laser controller (located on reverse side) are actively heated by three thirty watt heaters embedded in the mounting plate. Power to these heaters is routed through a non-resettable thermal fuse designed to break the connection at 80C.

3 Instrument Control

The main control unit is a microcontroller based control board with on board logic, capable of controlling all subsystems of the instrument. The unit consists of 6 power relay, four digital input channels and 2 digital output channels in addition to 4 UARTs and a Ethernet link.

Communication with the main control unit can be accomplished through either a telnet session made over the 10/100 host Ethernet link (wired through the Amphenol back plane connector) or through a dedicated RS485 link. A 1 Hz housekeeping stream consisting of five channels of temperature data is transmitted over the host Ethernet link to the (DHCP assigned) gateway address to maintain a record of instrument temperatures in the presence of a central ADC system. Details about the communication protocol can be found in section 3.

The six power relays on board server as interlocks to the five actively controlled heaters and the laser. Upon boot, the control board communicates with the heater controllers, sets their set point to -40C, closes the relays, then enters a sliding mode control scheme. The interlocks can be manually commanded though the RS285 or telnet host control, or automatically though updated firmware. Currently no firmware safety checks are in place, but may be added in the future.

The digital inputs provide information on the state of the laser as well as an event counter triggered by the camera. **Currently the camera is not correctly triggering the event counter and its input is not used.**

Figure 3.1: Main control board with terminals labeled. Main power, relays and digital IO lie along left side with all UARTs along right hand side.

The two digital outputs provide 10 mA @12VDC and are used to control the optoisolators on the 12VDC power supply unit. Setting the input to 1, pulls the pin high and disables the rail of the PSU. Power to the laser and camera is toggled by changing the state of the digital outputs.

The main control board serves as the central control point for the instrument, aggregating communication and control of all subsystems into a single unit while adding a user programmable layer of logic control. The layout of the board (depicted in figure 3.1) is divided into three main zones: Power relays/interlocks, Digital Inputs and Outputs (DIO), and communication UARTS.

All components are controlled using a register and state machine architecture. The device contains a set of registers which represent relay states, input/output logic levels and temperature values. Control and monitoring of the instrument, both externally through one of the host communication channels, or internally in the device logic is achieved through writing and reading these registers.
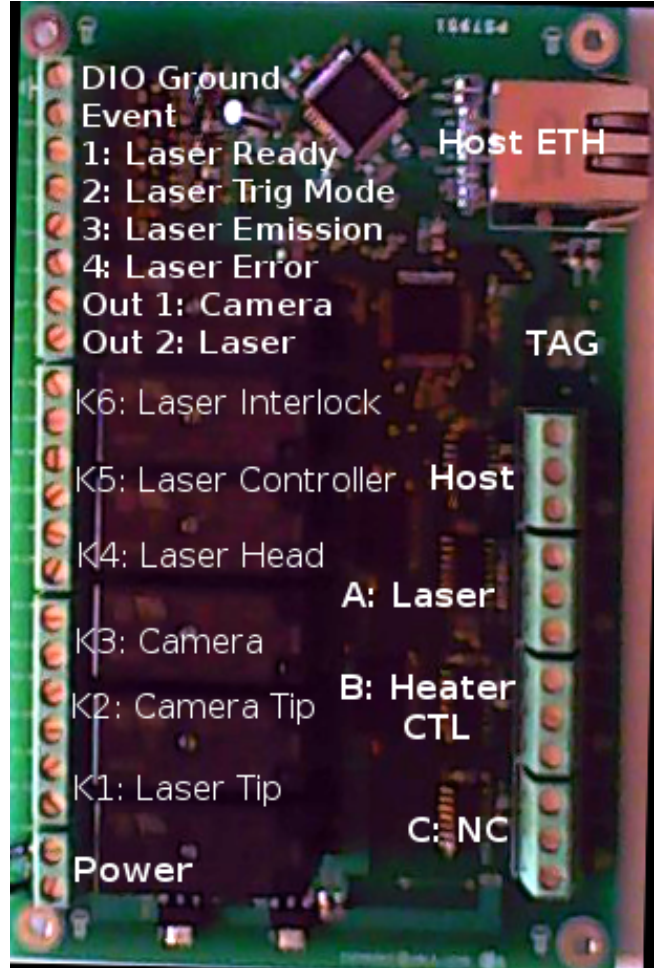
Relay Mapping		
Relay	**Device**	**Bitmask**
K1	Laser Tip	1
K2	Camera Tip	2
K3	Camera	4
K4	Laser Head	8
K5	Laser Controller	16
K6	Laser Interlock	32

Digital Input Output Mapping		
Pin	**Function**	**Bitmask**
GND	Ground	-
Event	Camera Frame Counter	-
In 1	Laser Ready	1
In 2	Laser Ext Trigger mode	2
In 3	Laser Emission	4
In 4	Laser Error	8
Out 1	Camera Power	1
Out 2	Laser Power	2

Table 3.1: Device mappings for power relays, digital inputs and digital outputs with register address bitmask

3.1 Power Relays/Interlocks

The power relays (labeled K1 through K6 in figure 3.1) are used as interlocks for the five PID controlled heater channels and the laser. The relays are normally open, preventing the heaters and laser from operating without the main control board in an online and functional state. Upon booting, the micro-controller closes all six relays at the end of its initialization sequence.

The state of the power relays is assigned to register 0 with each address represented as an integer bitmask. The relay mapping is described in the table below and in figure 3.1.

3.2 Digital Input/Outputs

The digital inputs (upper left of figure 3.1) are used to monitor digital output channels on the laser controller, allowing the status of the laser to be monitored in real time without polling the serial port. Digital inputs are assigned to register 1, as a integer bitmask. The digital pin mapping is described in the table below and in figure 3.1.

The digital outputs supply 12mA @12V to the logic ground (DIO GND) and are used to drive the optocouplers located in the 12VDC power supply unit. Setting these pins to high powers the optocouplers, disabling power to the rails. In this fashion, the digital output pins are used to control power to the laser and camera. Currently power to the laser and camera default to "ON" until the control board can boot, whereupon it disables the rails as part of the initialization sequence. Digital outputs are assigned to register 2 as an integer bitmask. The mapping of the output pins is described in the table 3.1 and in figure 3.1

3.3 Communication

The main control board serves as a central communication hub for all subsystems in the instrument. The communications system consists of four, high speed serial UARTS and a 10/100 TCP/IP port. Communication with the control board is accomplished through either the HOST RS485 port or the 10/100 ethernet port through a telnet session on port 23. Commands and replies to/from the control board are designed to be human readable but optimized for machine parsing. ****Currently the RS485 port does not seem to work, and only communication through ethernet is possible.**** Also, recently in the lab there had to be a router between the computer and Holodec in order to assign an IP address, which is one different to the computers assigned IP address by this router. If communication is not possible, check if there is a router connected, find the assigned IP address and try again.

The general format for all commands is:

$$:< command >;< argument1 >;< argument2 > \backslash r \backslash n$$

All commands **must** be started with a colon (:) and terminated with a newline (\r\n) with arguments separated by a semicolon (;). Failure to adhere to this convention will result in the command being ignored by the control board.

Reading Registers   Reading registers is accomplished with the **rd** command, which takes the register address as its only argument. Upon receiving a properly formatted read request, the control board responds with initial command with the requested value as argument two.

$$command \quad : rd; < register\ address >$$
$$reply \quad : rd; < register\ address >; < returned\ value >$$

Writing Registers   Writing to registers is accomplished with the **wr** command, which takes the register address as its first argument and the new value as its second. The control board responds with **ACK** for successful writes and **NAK** for unsuccessful writes.

$$command \quad : wr; < register\ address >; < new\ value >$$
$$reply \quad : wr; < register\ address >; ACK$$

A full list of commands and register addresses is included in section 3.5.

Laser Commands   Communication with the laser is performed by relaying commands through the control board (UART A) using the command **ua**. The command takes a single argument, which is the raw command to be sent to the laser controller. The control board automatically terminates the command with the newline character. All replies transmitted from the laser controller to the main control board over UART A will be mirrored to the host RS485 port as well as any open telnet sessions **regardless if a read command was issued**. A full list of laser commands is available in table 5.1.

3.4   Custom Programming

Updates to the main control board firmware are flashed with ICD-U64 in-circuit programmer through a tag-connect connector (labeled TAG in figure 3.1). The programmer and tag-connect cable are availible from:

tag-connect cable: `http://www.ccsinfo.com/product_info.php?products_id=Tag_Connect`
programmer   : `http://www.ccsinfo.com/product_info.php?products_id=icd_u64`

The firmware is written in C and requires the MPLAB C30 compiler and MPLAB IDE available from

`http://www.microchip.com`.

Interfaces			
UART	**Protocol**	**Speed**	**Comments**
Host	RS485	9600 8n1	Half duplex host communication wired through back plane connector
A	RS232	19200 8n1	Half duplex communication with laser controller
B	RS485	9600 8n1	Half duplex MODBUS communication with temperature controllers
C	RS485	9600 8n1	Unused
ETH	TCP/IP	10/100	10/100 Ethernet host communication

Table 3.2: Communication interfaces with protocol and configuration

3.5   Command Reference

command	arg1	arg2	Description
rd	register address	-	Read current value in register $< register\ address >$
wr	register address	new value	Write $< new\ value >$ to $< register\ address >$
ua	mirror string	-	Write $< mirror\ string >$ to UART A (Laser Controller)

Register Address	Name	Function
0	RELAY	Controls state of power relays. Bit 0 controls relay 1, etc
1	INPUT	Reads state of digital inputs. Bit 0 reads pin 1, etc
2	OUTPUT	Controls state of digital outputs. Bit 0 controls pin 1, etc
7	PV1	PV for heater controller 1
8	SP1	SP for heater controller 1
9	OP1	OP for heater controller 1
10	PV2	PV for heater controller 2
11	SP2	SP for heater controller 2
12	OP2	OP for heater controller 2
13	PV3	PV for heater controller 3
14	SP3	SP for heater controller 3
15	OP3	OP for heater controller 3
16	PV4	PV for heater controller 4
17	SP4	SP for heater controller 4
18	OP4	OP for heater controller 4
19	PV5	PV for heater controller 5
20	SP5	SP for heater controller 5
21	OP5	OP for heater controller 5
pv	PV all	PV for all channels returned as PV1,PV2,PV3,PV4,PV5
sp	SP all	SP for all channels returned as SP1,SP2,SP3,SP4,SP5
op	OP all	OP for all channels returned as OP1,OP2,OP3,OP4,OP5

In order to communicate via telnet, open telnet and type

$$open \ \ < IP\ address > \ 23$$

It will open the connection with specified IP address on port 23; for closing it press CRTL+]. Once the connection is open communication is possible, but only if the power of Holodec is on.

3.6 Specifications

DC Characteristics					
Characteristic	**Min**	**Typ**	**Max**	**Units**	**Comments**
DC Supply Voltage	10	12	15	VDC	
DC Supply Current	160	190	300	mA	Approximate current draw (from supply rail) at 32 MHz CPU operation, operating Ethernet link and 3 simultaneous RS-485 links. Maximum figure quoted for all relays actuated.
Operating Frequency	-	32	-	MHz	CPU operational freq (internal)
Digital Input Voltage	-	5	12	V	TTL voltages (zener diode protected)
Digital Output Voltage	-	12	15	V	Digital output is sourced by the input voltage rail
Digital Output Current	10	12	15	mA	Drives optically coupled inputs, current limited by 1K onboard resistor. Driven by DC supply voltage. Sources and sinks current.
Relay Output Current	4	-	5	A	Current through contactors
Event Counter Voltage	-	5	12	V	TTL voltages (Zener diode protected)
Operating Temperature	-40	-	85	C	Limited by silicon. Device operation below minimum temp may be unexpected and unpredictable

4 Heaters and Thermal Regulation

The Holodec II is equipped with six independantly controlled heated zones. These zones are designed to keep electronic components within their operating range or eliminate the buildup of ice and condensation on components exposed to the outside environment. These six zones are:

Power Distribution Plate   The rear-most plate holding the power distribution block, main control board and heater controllers is heated with three, 30W heaters and controlled by a creep action, bi-metal thermostat set at 0C. This heated zone is designed to bring the mission critical electronics back into their operational range in the event of a cold start condition. These heaters will run and maintain the rear plate at 0C as long as the probe has primary power.

Laser Controller / PSU   The middle plate holding the 12VDC power supply unit and laser controller is actively heated by three 30W heaters controlled by an Omega PID logic controller. Power to the heaters is connected through a non-resettable thermal fuse designed to break the connection at 80C. It is in place to prevent a severe over-temp condition caused by a loss of heater control.

Laser Head   The laser head is heated by four 50W heaters actively controlled by an Omega PID logic controller. Power to the heaters is routed through a resettable thermal breaker set at 50C. The thermal breaker is in place to prevent damage to the laser head from an over-temp condition.

Camera   The camera is actively heated by four 50W heaters controlled by an Omega PID logic controller. Power to the heaters is routed through a non-resettable thermal fuse designed to beak the connection at 72C. It is in place to prevent damage to the camera from an over-temp condition.

Laser and Camera Tips   Both laser and camera tips each contain 70W of heat, controlled by independent Omega PID logic controllers. These heaters are designed to prevent ice build up on the tips and clear fog from the optics. Typical operating temperature for the tips in flight is 50C.

4.1 Temperature Control

The five PID controlled heat zones are controlled by Omega CN7533 ramp/soak controllers pictured in figure 4. The current (process) temperature and the PID target (set point) temperature are displayed on the front LCD panel of each controller as indicated. Control of the heater controllers is managed by the main control unit which employs a sliding mode control scheme to limit the maximum thermal ramp rate of individual components.
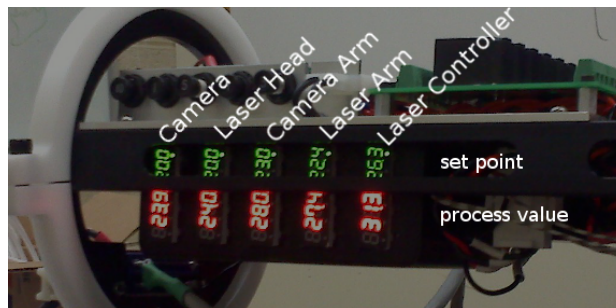

Figure 4.1: Layout of heater controllers. Controlled region is indicated.

Abbreviation	Value	Description
PV	Process Value	Current temperature value measured by thermocouple
SP	Set Point	PID target temperature
OP	Operating Point	Sliding mode target temp. SP is updated to drive PV towards OP

Table 4.1: Temperature values used in sliding mode control

The main control board is responsible for monitoring and communicating with the temperature controllers used to regulate the five heater circuits. All updates to the heater temperature controllers are performed by updating and reading registers on the main control board. See section 3 for details.

4.2 Sliding Mode Control

Each temperature controller uses PID logic to drive the process value (PV) towards the set point (SP). In order to limit the ramp rate to protect sensitive electronics, the main control board implements sliding mode control over the temperature controllers. This is accomplished by defining a "Operating Point" temperature (OP), which represents the final desired temperature for the channel, and smoothly updating the set point on the controller to move it towards the operating point at a controlled rate.

The main control board implements sliding mode control by monitoring the process value on a ten second interval. Each iteration, it computes the temperature difference between the process value and the operating temperature. If the difference is greater than 5C, it adjusts the set point on the controller to be 5C closer to the operating point than the current process value. In this fashion, the set point is updated every ten seconds until it is with $\pm 5C$ of the desired operating temperature.

Upon boot, the main control board defaults the operating point on all channels to 20C (room temperature). This value is hard coded into the firmware. Once the controller is online, the operating point can be updated manually by writing a new temperature to the appropriate register address in tenths of degrees C (e.g. $20.1C = 201$). The process value and set point for each controller are also accessible through individual registers. The full mapping is listed in table 3.5.

4.3 Overtemp Protection

(a)   (b)
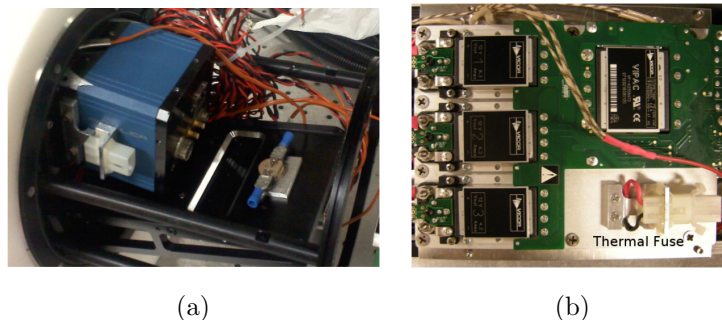
Figure 4.2: Location of thermal protection on camera and laser head (a) and PSU/laser controller (b)

The laser head, laser controller and camera heater circuits are also equipped with inline thermal interrupts in the form of thermal fuses (on the camera and laser controller) and thermal breakers (on the laser head). Figure 4.3 shows locations of mounting points. The thermal fuses mounted to the camera and PSU are designed to disconnect at 72C and 80C (respectively) and cannot be reset.

The thermal breaker is designed to trip at 45C and can be manually reset by depressing the reset switch.

4.4   Heater Controller Specifications

|	
Input Voltage	100 to 240VAC 50/60Hz
Operation Voltage Range	85% to 110% of rated voltage.
Power Consumption	5VA max.
Analog input	0 5V, 0 10V, 0 20mA, 0 50mV.
Control Output	Max. load 250VAC, 5A resistive load.
Sampling Range	Analog input: 150 ms per scan
RS-485 Communication	MODBUS ASCII/RTU communication protocol.
Vibration Resistance	10 to 55Hz, 10m=s^2 for 10 min, each in X, Y and Z directions.
Shock Resistance	Max. 300m/s^2, 3 times in each 3 axes, 6 directions.
Ambient Temperature	32F to 122F (0C to +50C). Functional to $\sim$ -20C (observed)
Storage Temperature	-4F to 150F (-20C to +65C).
Altitude	2000m or less.
Relative Humidity	35% tp 80% (non-condensing).

5 Optics and Imaging
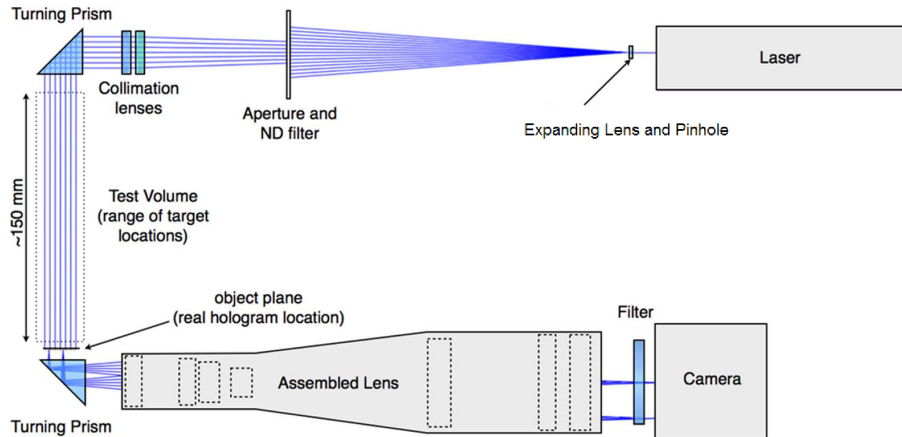
Figure 5.1: Layout of Holodec II imaging system

The holographic process involves illuminating the sample volume with a highly expanded and collimated beam and recording the resulting hologram. The Holodec II utilizes a 355nm Q-switched laser to generate laser pulses, which are expanded, filtered and collimated to form the illumination beam. This beam is steered by a turning prism in the instrument to illuminate the sample volume. An identical tip mounted to an imaging arm directly opposite the laser arm assembly, captures and magnifies the hologram which is then captured on a digital CCD camera. This layout is illustrated in figure 5.1.

5.1 Laser

The main illumination beam is generated by a Crylas FTSS355 passively q-switched, DPSS 355 nm laser which is divided into two parts: the laser head and the laser controller (figure 1.1). The laser controller is powered by the 12VDC power supply unit and uses a single RS232 UART for communication and control. The laser head is attached to the controller through a 26 pin D-subminiature connector. In order to maintain stability, once warmed up, the laser head must stay within $\pm$3C of its initial temperature and cannot change faster than 3C per hour.

5.1.1 Beam Expansion and Filtering

The primary beam expansion and

ltering optics are contained within the primary beam conditioning assembly, which is mounted directly to the laser aperture, creating one self contained unit (shown in figure 5.2). The assembly consists of a 75 μm pin hole mounted close to the focus of a 2.5 mm diameter, 3 mm focal length converging lens. Alignment of components is set at time of fabrication and is not meant to be field adjusted.

NOTE: The primary beam conditioning assembly is aligned to obtain an optimal beam profile after being mounted to the laser head. To maintain laser profile, the orientation of the assembly must be maintained.

Command	Parameter	Explanation
st	-	Laser is turned on, Laser emission starts.
rs	-	Laser is turned off, laser emission is stopped immediately
vs	-	Display operation byte and status byte (hex format)
et	0 , 1	0: Trigger mode is set to Internal 1: Trigger mode is set to External
mf	1...30000	Sets the actual repetition rate for internal trigger mode. The repetition is limited by a value, which can be requested by the mm command.
mm	-	The maximum allowed repetition rate is requested
re	-	Clearing actual error condition
er	-	Display last error code
ve	-	Display event memory
id	-	Display model type of control unit and the firmware version
im	-	Display laser head identification data: laser type (8 chars.), serial number (8 chars.), shipping date (6 chars.) and optionally additional info text (16 chars.)
ee	-	Enable access to the laser head memory
ed	-	Disable access to the laser head memory
es	-	Save actual parameters in the laser head memory
el	-	Load actual parameters from the laser head memory
?	-	Display list of commands

Table 5.1: Laser Controller Commands

5.1.2 Mounting

The laser head is mounted to the laser head mounting plate with six 4-40 (3/32") socket cap screws. The mounting fit tolerance is sufficiently loose to allow minor adjustments to the beam profile by altering the position of the laser head prior to torquing the mounting screws.

5.1.3 Control

Laser control is acheived by relaying commands to the laser controller though the main control board using the ua command. A full description of this command can be found in section 3.3, and a full list of commands found in table 5.1.

5.2 Laser Optics

After leaving the primary beam conditioning assembly, the beam passes through an aperture in the instrument bulkhead and into the laser arm where it is allowed to freely expand and propagate towards the laser tip before entering the final collimation and filtering stage. This stage is responsible for truncating the expanded field and collimating the resulting beam to form a flat, uniform field.

bit	bitmask	Operation byte	Status byte
0	1	TEC1 On	TEC1 OK
1	2	TEC2 On	TEC2 OK
2	4	Laser On	Laser OK
3	8	Modulation On	Modulation On
4	16	Master Mode On	Laser ready
5	32	Debug mode On	Set parameters
6	64	Memory access On	Interlock
7	128	Power regulation mode On	Fatal error

Table 5.2: Operating and Status byte code mapping
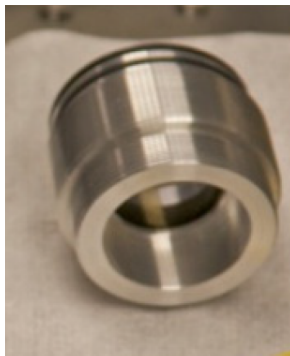
(a) Collimation optics assembly. Unit threads into laser arm and laser tip

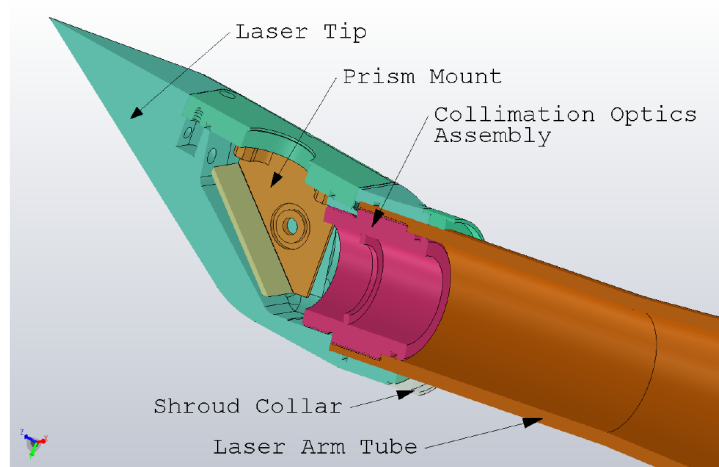(b) Schematic cross section of laser collimation optics installation.

The final aperture and collimation optics are a modular unit inserted into the tip-end of the laser arm. The collimation optics (shown in figure 5.2(a)) are built into a machined assembly which serves as the mating coupler between the the laser tip and laser arm. The threads mating the laser tip to the assembly are coated with a thread sealing compound which should result in the assembly remaining mated to the tip (unscrewing from the arm) during removal. If the assembly should come loose from the laser tip, care must be taken to avoid contamination of the prism in the tip.

5.3 Tips

5.4 Camera

The camera is a Prosilica (now Allied Vision) GE4900 CCD camera. It captures a single 4872x3248 pixel frame ate a rate of 3.3 frames per second. It is powered by the 12VDC power supply unit and streams data directly to the instrument data system over a dedicated patch of cat 6 Ethernet cable. Control of the camera is accomplished through provided software over the ethernet link. There is no communication between the instrument's main control unit and the camera other than the ability to power cycle the camera.
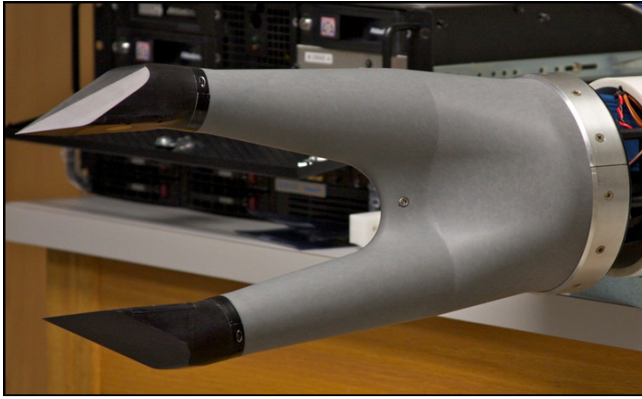
(a) Front of probe with shroud installed
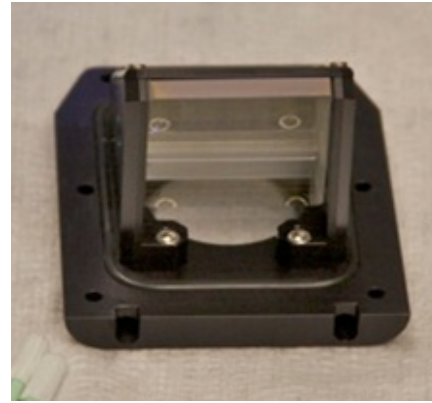
(b) Close up of prism mounted underside of tip window plate. Rectangular holes visible along edge are for anti-fog heaters

5.5 Imaging Optics
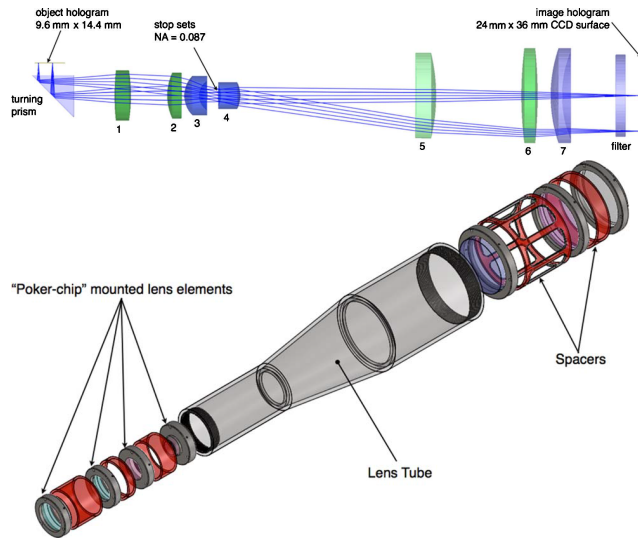
Sensor Type	Kodak KAI-16000
Sensor Shutter Type	Progressive Interline
Image Resolution	4872 x 3248 pixels
Pixel Size	7.4m x 7.4m
Optical Format	35mm optical format (43.3mm physical diagonal)
Lens Mount	Nikon Bayonet (F-mount) -adjustable
Color Sensor Filter Pattern	Bayer
Full Resolution Frame Rate	3.35 fps
Frame Rate (1024 x 1024 ROI)	7.04 fps
I/O	1 isolated TTL compatible input 3 isolated TTL compatible outputs
Power Requirements	Less than 6.0W
Digitization	12 Bits
Trigger latency	4.2s
Trigger Jitter	$\pm 10 ns$
Tpd	90ns
Operating Temperature	0 to 50 Celsius
Operating Humidity	20 to 80% non-condensing
Size	66mm (height) x 66mm (width) x 110mm (length)
Weight	395g (406g for GE4900C)
Hardware Interface Standard	IEEE 802.3 1000BASE-T, 100BASE-TX
Software Interface Standard	GigE Vision Standard 1.0

6 Instrument Data System

The Holodec II is capable of generating approximately 600 Gb of data per hour, requiring a large amount of on board storage to accommodate multiple hour flights. To reduce costs and simplify the data offload process, the data system utilizes 3.5" SATA hard drives as removable media which mount in front loading drive bays (marked A and B in figure 6.1). The instrument data system also contains an RS485 card used for direct communication with the instrument control board. A labview-based control program on the data system provides a simple graphical interface to the instrument's systems.

6.1 Installation

The data system chassis is designed to mount in standard 19" rack, but can be mounted vertically if required provided adequate clearence along the front and rear of the chassis. Figure 6.1 b shows the rear connections for the data system, which include a Cat6 ethernet patch running to directly to the instrument camera and a single RS485 connection. The data system has both RS232 and RS485 cards, which are labeled in the figure as well as on the physical chassis. The RS232 ports are only in place for debugging and are not used with the instrument.

The instrument data system starts a VNC server upon boot, allowing it to run completely headless if connected to the aircraft data network through the onboard NIC.

6.2 Instrument Control

The instrument data system is equipped with a RS485 card (figure 6.1 b) for direct interface with the instrument. Control can be accomplished through either direct terminal access or through a labview based, graphical software package. The front panel and associated subpanels are shown in figure 6.2.

The control software is capable of communicating with the instrument over either the RS485 port or through a telnet connection. **Note: The RS485 connection seems to not work currently.** The connection settings can be updated through the "Com Settings" panel which is accessible by pressing the button adjacent to the "COM Status" indicator. Updating the com parameters will update the connection settings in real time.

(c) Data system front

(d) Data system back

Figure 6.1: Front and rear views of the instrument data system with key components labeled

Figure 6.2: Holodec Control front panel (far left) with subpanels. The top pane in the front panel controls and indicates power to the laser and camera. The"Laser Control" pane shows the status of the laser and provides the switch to start laser emission when the laser is in the "ready" state. The Interlock Status pane indicates the status of the interlocks with the option to open a subpanel for more granular control. The Heater Status pane shows the current temperature and operating point for the five managed channels as well as an status indicator light. The anti-ice button at the bottom of the pane toggles the anti-ice mode which elevates the temperature of the instrument tips to the specified temperature (default 50C). This panel also has the option to open a subpanel which shows historic temperature data and includes the ability to alter the operating point of individual channels. At the bottom of the front panel is a com status light that indicates the status of the connection to the instrument and a button to open the com settings subpanel. The SCRAM button provides an emergency shutdown mechanism which opens all interlocks and kills power to the laser and camera.

Camera Control Power to the camera is controlled through the top pane in the front panel through the "Camera Power" switch. This switch is constantly updated to reflect the currents state of the camera power register on the main control board. Toggling its state will send the appropriate command to the control board to enable or disable power. All of the camera configuration settings are handled through the camera driver over the data connection, so all configuration is handled inside of streampix. Toggling power is the only option available for the camera through the control board.

Laser Control The second button labeled "Laser Power" at the top of the front panel toggles power to the laser. The laser has a warm up period that can last several minutes. Once the laser has fully warmed up, the "Ready" indicator will illuminate, enabling the "Emission" button. Toggling the "Emission" switch to "ON" will begin laser emission. If a critical error occurs in the laser head, the "Error" light will illuminate. **This indicates a major error within the laser controller or laser head, which will require factory servicing**.

Interlock Control The interlocks are in place as a safety factor to ensure that all systems are under control before being enabled. As such, manually toggling the interlocks should only be done under unusual circumstances. The "Interlock Status" panel shows two indicator lights to show the status of the heater and laser interlocks. Individual control over the interlocks can be achieved by opening the interlock status subpanel.

Temperature Control The main control board defaults all heaters to 20C, which should be sufficient for most flying conditions. In some situations, it will be necessary to warm the tips above this point to shed ice and defog the optics. This can be easily accomplished on the front panel by enabling "Anti-Ice" mode. Anti-Ice mode sets the operating temperature of the instrument's tips to the temperature listed in the box next to the switch (50C default). Updating this temperature will dynamically update the operating temperature of the two arms. Toggling anti-ice mode off resets the operating point of the tips to 20C. The temperature of all components can be more closely monitored in the Heater Status subpanel, which also allows all five operating temperatures to be manually updated.

As an emergency measure, a SCRAM button is located at the bottom of the front panel. This button disables power to the laser and camera, resets all heater controllers to their default operating temperature and opens all of the interlocks. It is intended as a panic button in the event the instrument needs to be rapidly shut down.

6.3 Loading Data Drives

The instrument data system uses dual 3.5" SATA platter drives built into a RAID1 array as removable storage media. The RAID1 array helps protect against missed writes due to vibration and shock present in the aircraft environment. The duplicate drives also give better data security after being removed from the aircraft, allowing one copy to be safely archived, leaving the other safe for analysis. These drives are mounted in sled-less, front access drive bays shown in figure 6.1 and figure 6.3. Each drive bay is secured with a lock which also acts as a switch to enable the drive bay. **It is important to lock the drive bays before powering on the system to ensure the drives are properly recognized.**

Once the drives are locked in place, and the computer started, the on board RAID card should detect the array and determine its health. In some instances, the disc arrays may be prebuilt for the field campaign, in which case the arrays just need to be verified as being healthy. If the arrays are being initialized on the spot, the discs will need to be built into an array and formatted using the software utilities found on the instrument data computer.

(a) Instrument data system with data drive bay doors open and drives partially removed.

(b) Drive bay showing locking key in place

Figure 6.3: Top image shows two 3.5" SATA drives being removed or inserted into the drive bays. Bottom image shows the bay door in the closed and locked position, ready for the computer to be turned on. The data drives exist in matched pairs, built into a RAID1 array and need to be handled as such.

6.4 RAID Managment

For a field campaign, all drive sets should be prebuilt into RAID1 arrays, which will not require any additional maintenance. If the RAID set is not prebuilt, or if the drives are not correctly installed when the data system computer is first booted, the RAID will need to be rebuilt.

The RAID is managed with a JMicron hardware RAID controller and is managed through the JMicron RAID utility. This utility should start automatically when the data system computer boots, but can be started manually though the icon located on the desktop. The utility is accessed through the icon located in the system tray.

To rebuild the RAID, open the JMicron control software, and enter into the configuration mode tab located on the bottom left of the utility. Both drives should be listed to the right. If they are not, verify that both bays are closed and locked and with an illuminated blue status light. Select "RAID1" from the list and accept the warning about data loss. The two drives are now built into an array.

The array now needs to be initialized for windows to recognize it. Right click on the "Holodec" icon with the symbol of a computer, and select "manage". Navigate to the "Disk Management" option on the left, locate the new volume and initialize it with the following settings:

Type	Simple Volume
Drive Letter	E
Format	NTFS
Volume Label	RF0#

6.5 Data Acquisition

Data acquisition is accomplished through a direct gigabit Ethernet link between the camera on-board the instrument and a high speed Ethernet card on board the instrument data system (shown in figure 6.1). Data is acquired over this link using a software frame grabber (Streampix) which is writes directly to the data disk array.

To begin data acquisition, ensure the camera and laser are powered on (see section 6.2). When the camera comes online, Windows will detect and indicate the new connection. Once the camera is online, open up StreamPix through the link on the desktop.

Note: StreamPix automatically detects the camera and starts the frame grabber when it starts. If the camera is not online when StreamPix starts, or if the camera was powered down before StreamPix was previously closed, StreamPix will need to be manually configured to read the camera. The menu used is

$$Hardware \rightarrow Prosilica \rightarrow GigE.$$

This is illustrated in figure 6.5 a.

When StreamPix is configured properly and the laser is emitting, a hologram should appear in the main window. At this point, the data system is ready to begin recording. To begin a new sequence, go to

$$File \rightarrow new\ sequence\ on\ disk$$

or

$$Home \rightarrow StreamPix\ Settings \rightarrow Workspace(?)$$

and save a new sequence on the RAID array. Now return to the main window and find the record button shown in figure 6.5 b. Depressing this button will begin recording.

Scripting For easier data handling after data acquisition, it is of advantage to store many small sequence files instead of one large one. This can be achieved by scripting within StreamPix. There is a script currently already written and it will be used during recording. It should be recognized automatically, but it can also be manually selected. To use or change it, go to

$$Home \rightarrow StreamPix\ Settings \rightarrow Recording\ Rate$$

and check the box "use a recording script"; then you can go to "edit script". The script that is currently saved there records 100 frames and creates a new file afterwards. During recording the number of the current hologram is shown above the frame and that will reset and start counting again after each loop of the script, i.e. after the specified number of frames (currently 100).
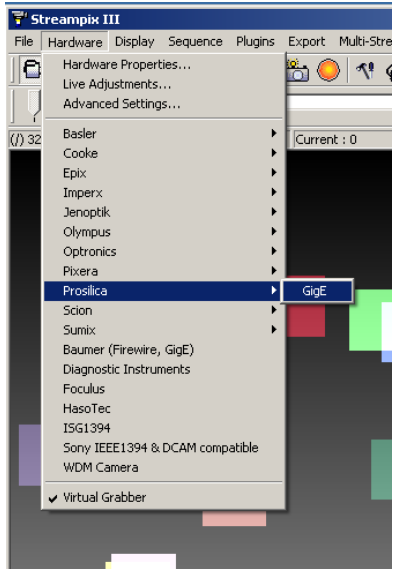
(a) Menu sequence to enable the proper frame grabber

(b) Location of record button on StreamPix toolbar

7 Operations Checklist

Data System IP	
Holodec IP	
Holodec COM port	

7.1 Roll out

☐ Verify Data Computer Offline

☐ Data Drives Installed

☐ Drive Bays Locked

☐ Data Computer Power On

☐ Synchronize Time with NTP

☐ Verify RAID Status and Rebuild (if necessary)

7.2 Taxi

☐ Close Breaker

☐ Open Holodec Control

7.3 Take Off

☐ Camera Power: Enable and Verify

☐ Laser Power: Enable and Verify

☐ Laser Ready

☐ Begin Emission

☐ Open Streampix

☐ Select Prosilica Frame Grabber (if needed)

☐ Begin Recording

7.4 Pre-Landing

☐ Stop Recording

☐ Close Streampix

☐ Laser Power: Disable and Verify

☐ Camera Power: Disable and Verify

☐ Close Holodec Control

☐ Shutdown Data System

7.5 Taxi

☐ Open Breaker

7.6 Offload

☐ Verify Data Computer Offline

☐ Unlock Data Drives

☐ Remove Drives

8 Troubleshooting

8.1 Communication

If no communication is possible (either through Holodec Control or a telnet session), there can be several reasons for this. Currently, the RS485 connection does not work, so try changing to ethernet connection first. If that also doesn't work, check if the used IP address is correct. A router assigns an IP address to Holodec, and that has to be used. If all else fails, check if the pinouts are correctly wired. The correct wiring is shown in the Appendix. A telnet session can be established as described in section 3.

8.2 Holodec Control

Grey buttons in Holodec Control or no values for the heaters could show that the connection is not working (reasonable values from the heaters should be shown immediately after a successful connection). First, check if power is on; if it is still not working, check if the correct connection type is used. Only ethernet works currently, and the correct IP address has to be used with it and it might be different to the default.

8.3 StreamPix

If StreamPix doesn't find the camera, check if the camera power is on, then click in the empty StreamPix screen and choose the correct camera driver (Prosilica GigE or AVT).

If StreamPix shows a black screen, check if the blue safety caps from Holodecs tips are removed, there are no other obstacles in the laser beam, the laser power is switched on and the green button in Holodec Control for "Emission" is lit. In case the screen is still black, either check if the laser really emits (by e.g. holding a white sheet of paper in the laser beam) or, if all else fails, try to increase the gain in StreamPix. This last measure helps if the laser is very weak, but still emitting, but should not be necessary for a healthy laser, so if this has to be done, please note this as it is not a longterm fix. In any case, **do not change the exposure time of the camera or the laser repetition rate!** If you have reason to believe they are wrong, check their values first. They are both matched (camera exposure time = 1/laser repetition rate), so the camera records one laser pulse per frame; more pulses per frame would result in a double exposure which leads to useless holograms. The laser repetition rate is supposed to be 1 kHz (determinable e.g. through a telnet session), the camera exposure time 1 ms (determinable in StreamPix).

9   Appendix

A   Control Board
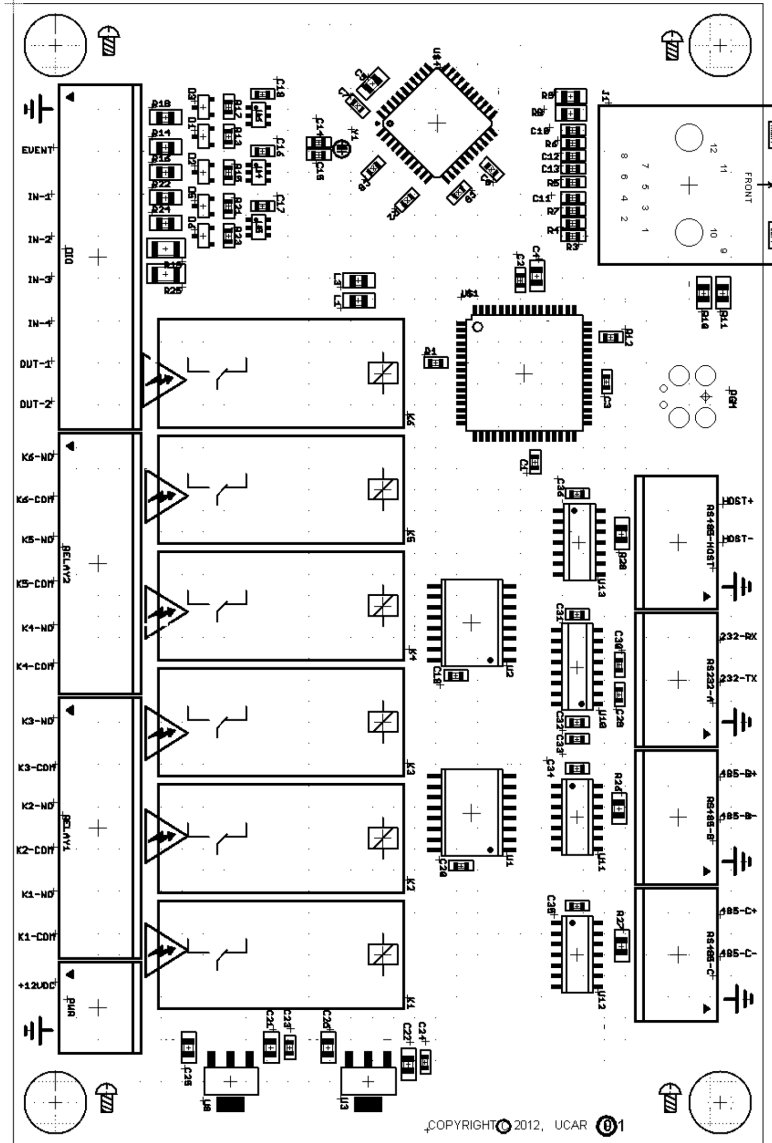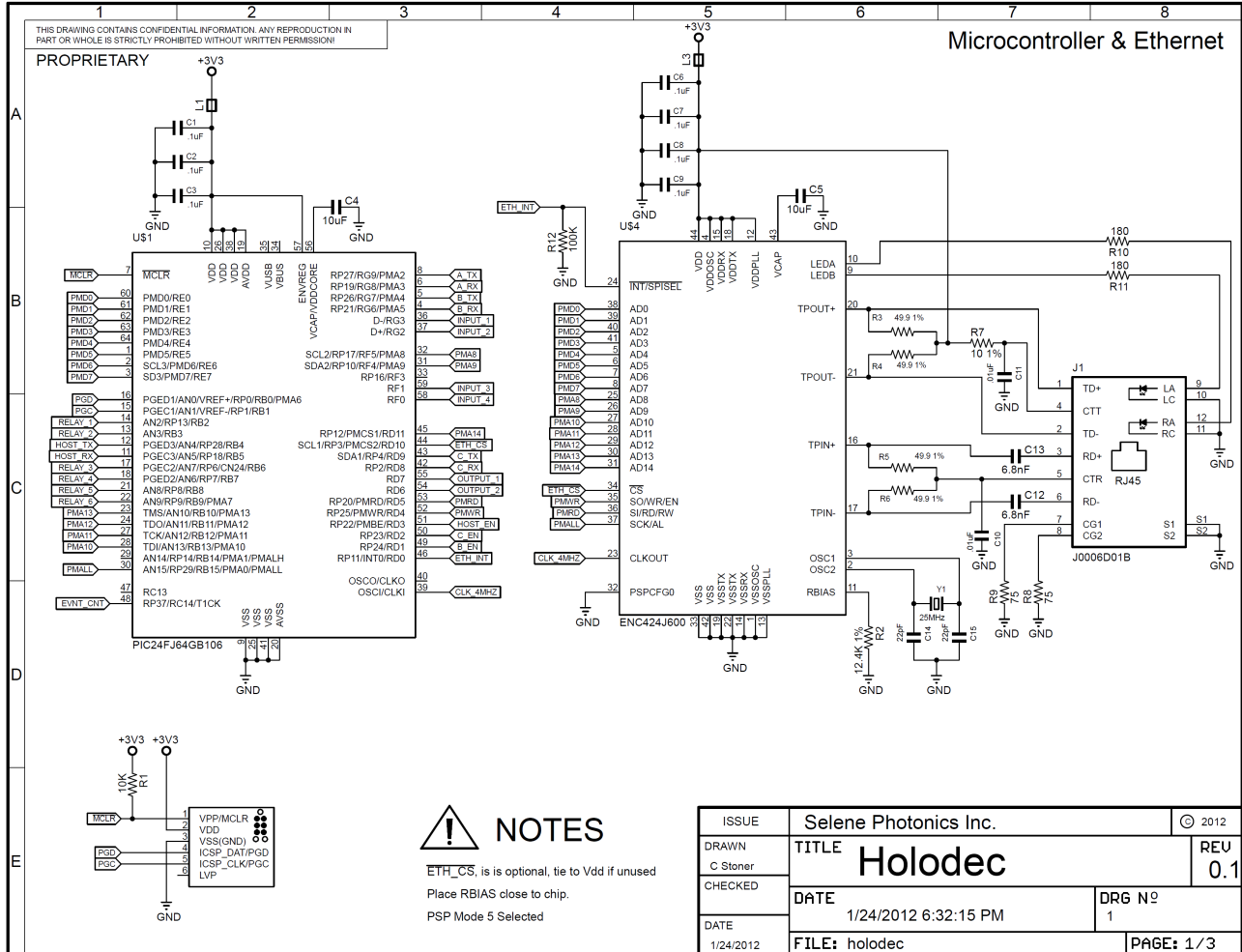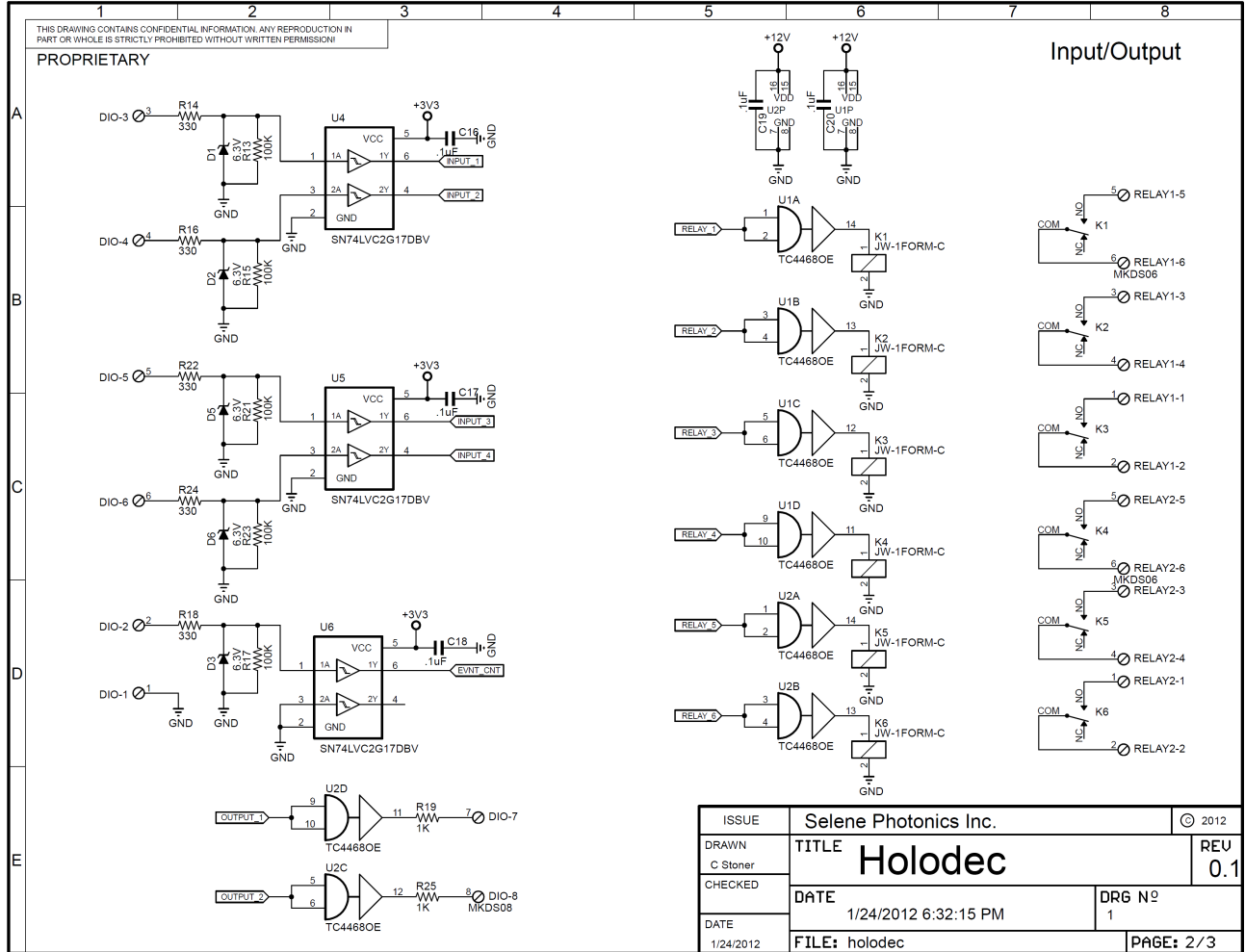
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PROPRIETARY

Microcontroller & Ethernet

+3V3

C1 .1uF
C2 .1uF
C3 .1uF
GND
U$1

C4 10uF
GND

ETH_INT

+3V3
L3
C6 .1uF
C7 .1uF
C8 .1uF
C9 .1uF
GND
U$4

C5 10uF
GND

R12 100K
GND

180 R10
180 R11

PIC24FJ64GB106

MCLR
PMD0/RE0
PMD1/RE1
PMD2/RE2
PMD3/RE3
PMD4/RE4
PMD5/RE5
SCL3/PMD6/RE6
SD3/PMD7/RE7

PGED1/AN0/VREF+/RP0/RB0/PMA6
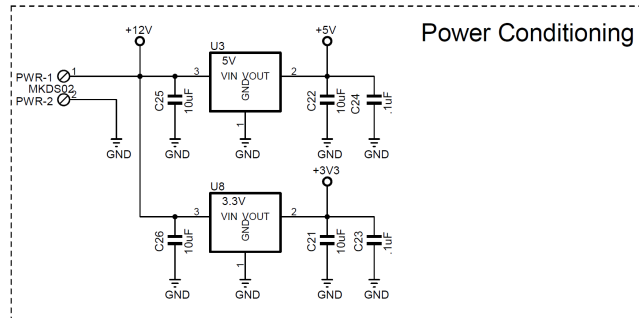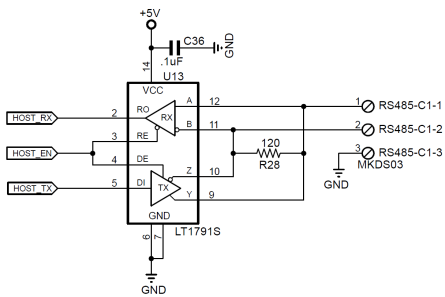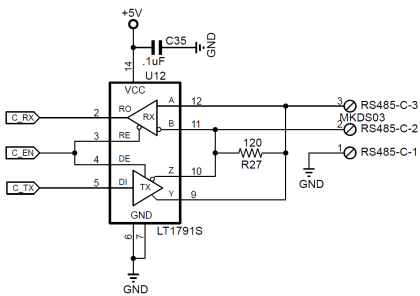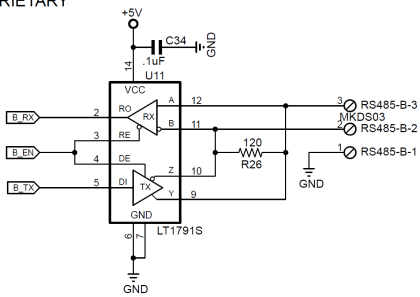PGEC1/AN1/VREF-/RP1/RB1
AN2/RP13/RB2
AN3/RB3
PGED3/AN4/RP28/RB4
PGEC3/AN5/RP18/RB5
PGEC2/AN7/RP6/CN24/RB6
PGED2/AN6/RP7/RB7
AN8/RP8/RB8
AN9/RP9/RB9/PMA7
TMS/AN10/RB10/PMA13
TDO/AN11/RB11/PMA12
TCK/AN12/RB12/PMA11
TDI/AN13/RB13/PMA10
AN14/RP14/RB14/PMA1/PMALH
AN15/RP29/RB15/PMA0/PMALL

RC13
RP37/RC14/T1CK

VDD VDD AVDD
ENVREG
VCAP/VDDCORE
VUSB VBUS

RP27/RG9/PMA2
RP19/RG8/PMA3
RP26/RG7/PMA4
RP21/RG6/PMA5
D-/RG3
D+/RG2

SCL2/RP17/RF5/PMA8
SDA2/RP10/RF4/PMA9
RP16/RF3
RF1
RF0

RP12/PMCS1/RD11
SCL1/RP3/PMCS2/RD10
SDA1/RP4/RD9
RP2/RD8
RD7
RD6
RP20/PMRD/RD5
RP25/PMWR/RD4
RP22/PMBE/RD3
RP23/RD2
RP24/RD1
RP11/INT0/RD0

OSCO/CLKO
OSCI/CLKI

VSS VSS VSS AVSS

GND

A_TX
A_RX
B_TX
B_RX
INPUT_1
INPUT_2
PMA8
PMA9
INPUT_3
INPUT_4
PMA14
ETH_CS
C_TX
C_RX
OUTPUT_1
OUTPUT_2
PMRD
PMWR
HOST_EN
C_EN
B_EN
ETH_INT

CLK_4MHZ

MCLR
PMD0
PMD1
PMD2
PMD3
PMD4
PMD5
PMD6
PMD7

PGD
PGC
RELAY_1
RELAY_2
HOST_TX
HOST_RX
RELAY_3
RELAY_4
RELAY_5
RELAY_6
PMA13
PMA12
PMA11
PMA10
PMALL

EVNT_CNT

ENC424J600

INT/SPISEL
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
AD8
AD9
AD10
AD11
AD12
AD13
AD14
CS
SO/WR/EN
SI/RD/RW
SCK/AL
CLKOUT
PSPCFG0

VDD VDDOSC VDDRX VDDTX VDDPLL VCAP
LEDA
LEDB
TPOUT+
TPOUT-
TPIN+
TPIN-
OSC1
OSC2
RBIAS

VSS VSS VSSTX VSSTX VSSRX VSSOSC VSSPLL

GND

PMD0
PMD1
PMD2
PMD3
PMD4
PMD5
PMD6
PMD7
PMA8
PMA9
PMA10
PMA11
PMA12
PMA13
PMA14
ETH_CS
PMWR
PMRD
PMALL

CLK_4MHZ

GND

R3 49.9%1
R4 49.9%1
R7 10 1%
.01uF C11
GND

R5 49.9%1
R6 49.9%1
C13 6.8nF
C12 6.8nF

.01uF C10
GND

C14 22pF
C15 22pF
Y1 25MHz
R2 12.4K 1%
GND GND

R9 75
R8 75
GND GND

J1
TD+
CTT
TD-
RD+
CTR
RD-
CG1
CG2
LA
LC
RA
RC
S1 S2
RJ45
J0006D01B
GND

S1 S2
GND

+3V3 +3V3
10K R1
MCLR

1 VPP/MCLR
2 VDD
3 VSS(GND)
4 ICSP_DAT/PGD
5 ICSP_CLK/PGC
6 LVP

PGD
PGC
GND

⚠ NOTES

ETH_CS, is is optional, tie to Vdd if unused

Place RBIAS close to chip.

PSP Mode 5 Selected

ISSUE	Selene Photonics Inc.		© 2012
DRAWN			REV
C Stoner	TITLE **Holodec**		0.1
CHECKED			
	DATE	DRG №	
DATE	1/24/2012 6:32:15 PM	1	
1/24/2012	FILE: holodec		PAGE: 1/3

PROPRIETARY

Input/Output

ISSUE	Selene Photonics Inc.		© 2012
DRAWN C Stoner	TITLE **Holodec**		REV 0.1
CHECKED	DATE 1/24/2012 6:32:15 PM	DRG Nº 1	
DATE 1/24/2012	FILE: holodec		PAGE: 2/3

RS485 2-wire

Pin	SIGNAL
1	Data -
2	Data +
3	NC
4	NC
5	GND
6	NC
7	NC
8	NC
9	NC
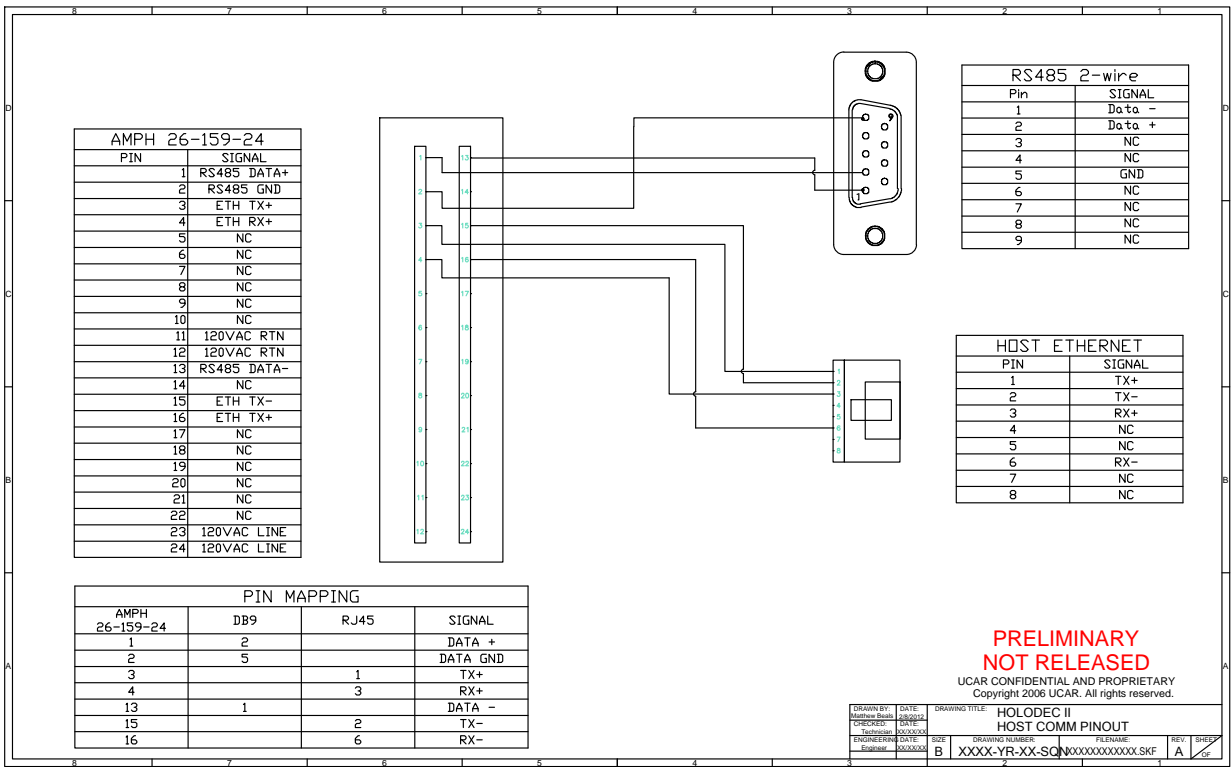
AMPH 26-159-24

PIN	SIGNAL
1	RS485 DATA+
2	RS485 GND
3	ETH TX+
4	ETH RX+
5	NC
6	NC
7	NC
8	NC
9	NC
10	NC
11	120VAC RTN
12	120VAC RTN
13	RS485 DATA-
14	NC
15	ETH TX-
16	ETH TX+
17	NC
18	NC
19	NC
20	NC
21	NC
22	NC
23	120VAC LINE
24	120VAC LINE

HOST ETHERNET

PIN	SIGNAL
1	TX+
2	TX-
3	RX+
4	NC
5	NC
6	RX-
7	NC
8	NC

PIN MAPPING

AMPH 26-159-24	DB9	RJ45	SIGNAL
1	2		DATA +
2	5		DATA GND
3		1	TX+
4		3	RX+
13	1		DATA -
15		2	TX-
16		6	RX-

PRELIMINARY
NOT RELEASED

DRAWN BY: Matthew Beals	DATE: 2/8/2012	DRAWING TITLE: HOLODEC II HOST COMM PINOUT			
CHECKED: Technician	DATE: XX/XX/XX				
ENGINEERING Engineer	DATE: XX/XX/XX	SIZE B	DRAWING NUMBER: XXXX-YR-XX-SQN	FILENAME: XXXXXXXXXXXX.SKF	REV. A	SHEET OF