iC212
HIGHSPEED PHOTORECEIVER

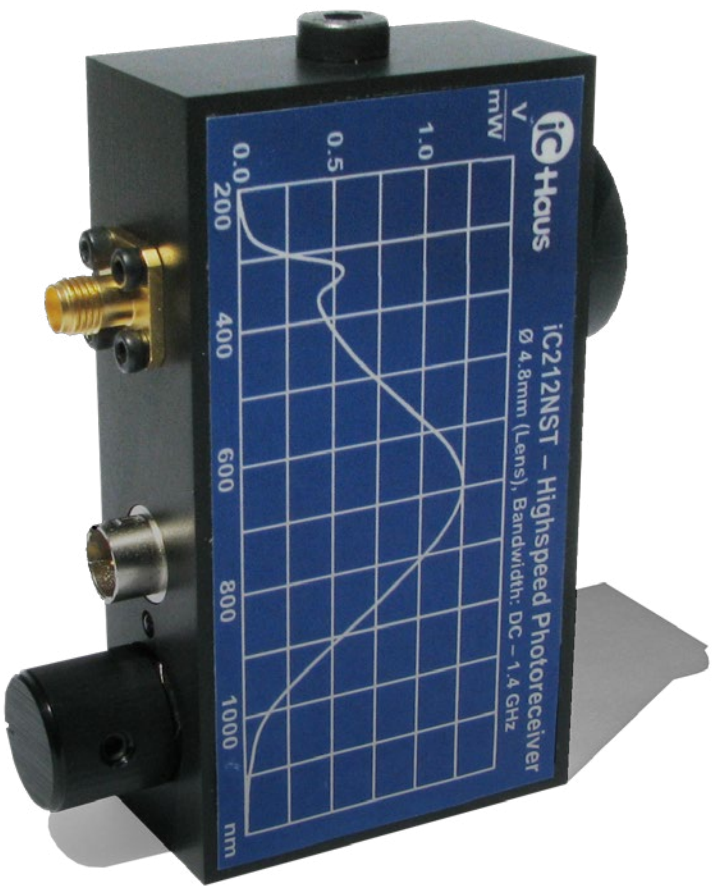
FEATURES

- Bandwidth DC to 1.4 GHz
- Si PIN photodiode, Ø 0.2 mm for "No Slow Tail" (NST) option
- InGaAs photodiode, Ø 0.1 mm for "Near Infrared" (NIR) option
- Spectral response range λ = 320 to 1000 nm (NST)
- Spectral response range λ = 800 to 1800 nm (NIR)
- Amplifier transimpedance (gain) 3.125 V/mA
- Max. conversion gain 1.25 V/mW @ 700 nm (NST)
- Max. conversion gain 3.25 V/mW @ 1500 nm (NIR)

APPLICATIONS

- Fast pulse and transient measurement
- Optical front-end for oscilloscopes

DEVICE



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DESCRIPTION

The iC-Haus Highspeed Photoreceiver iC212 has been developed for optical high speed measurement. With its bandwidth ranging from DC up to 1.4 GHz it detects photo signals from constant light to high speed with rise times down to 200 ps. The iC212 Highspeed Photoreceiver also features offset adjustment to compensate DC levels of the input signal.

The photodiode used with the standard "no slow tail" (NST, blue label) version covers a spectral range from 320 to 1000 nm with an active area diameter of about Ø 0.2 mm, which is increased by a Ø 4.6 mm lens, resulting in an effective usable area of typical 12.5 mm².
The Highspeed Photoreceiver is able to detect power levels in the sub mW range at GHz speed.

The "Near Infrared" (NIR, orange label) version covers a spectral range from 800 to 1800 nm.

The iC212 Highspeed Photoreceiver comes with M6 mounting holes for integration in optical bench systems and an optional fiber-optic input adapter for optical fiber coupling.

ABSOLUTE MAXIMUM RATINGS

Beyond these values damage may occur; device operation is not guaranteed.

Item No.	Symbol	Parameter	Conditions	Min.	Max.	Unit
G001	Pmax	Optical Input Power			10	mW
G002	Vs	Power Supply Voltage			±20	V

ELECTRICAL CHARACTERISTICS

Test Conditions: Vs = ±15 V, Ta = 25 °C*, System Impedace 50 Ω

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Gain							
101	A	Amplifier TransimpedanceConversion Gain	50 Ω load; NST: λ = 700 nm NIR: λ = 1500 nm		3.125 1.25 3.25		V/mA V/mW V/mW
Frequency Response							
201	fmax	Upper Cut-Off Frequency	-3 dB		1.4		Ghz
202	ΔA	Gain Flatness			±1		dB
203	tr	Rise Time	10 to 90%		280		ps
204	tpd	Propagation Delay	optical in => electrical out, 50% to 50%		750		ps
Detector							
301	d	Active Area Diameter	NST NIR		0.2 0.1		mm mm
302	Aeff	Effective Active Area	4.6 mm lens		12.5		mm²
303	λ	Spectral Range	NST NIR	320 800		1000 1800	nm nm
304	Pmax	Max. Optical Input Power	NST: average NST: linear amplification @ 700 nm NIR: linear amplification @ 1500 nm		10 770 320		mW µW µW
305	NEP	Noise equivalent power	including amplifier noise, f = 1 GHz (see Fig. 23)		115		pW/$\sqrt{\mathrm{Hz}}$
Output							
401	Rout	Output Impedance			50		Ω
402	Vout	Output Voltage Swing	50 Ω load, for linear amplification	-0.3		1.0	V
403	Vos	Offset Voltage (adjustable)†	DC offset cancellation	-1.25		0.15	V
404	Pos	Offset (adjustable)†	equivalent optical power	-92		750	µW
405	twu	Warm-Up Time	stable offset voltage		30		min

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ELECTRICAL CHARACTERISTICS

Test Conditions: Vs = ±15 V, Ta = 25 °C*, System Impedace 50 Ω

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Power Supply							
501	Vs	Supply Voltage				±15	V
502	Is	Supply Current		±150			mA

* Caution! Even during regular operation, the aluminum case of the photoreceiver may heat up to 40 °C max.
† The output is clipped to -0.5 V, if the offset voltage is less than 0.5 V and no DC light is present.

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CONTENTS

The purchased parts package includes

- Highspeed Photoreceiver iC212 (picture shows standard NST option)
- Power adapter (230 VAC)
- Coaxial cable with SMA plugs
- SMA to BNC adapter
- Fiber adapter

Figure 1: Box contents

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DIMENSIONS

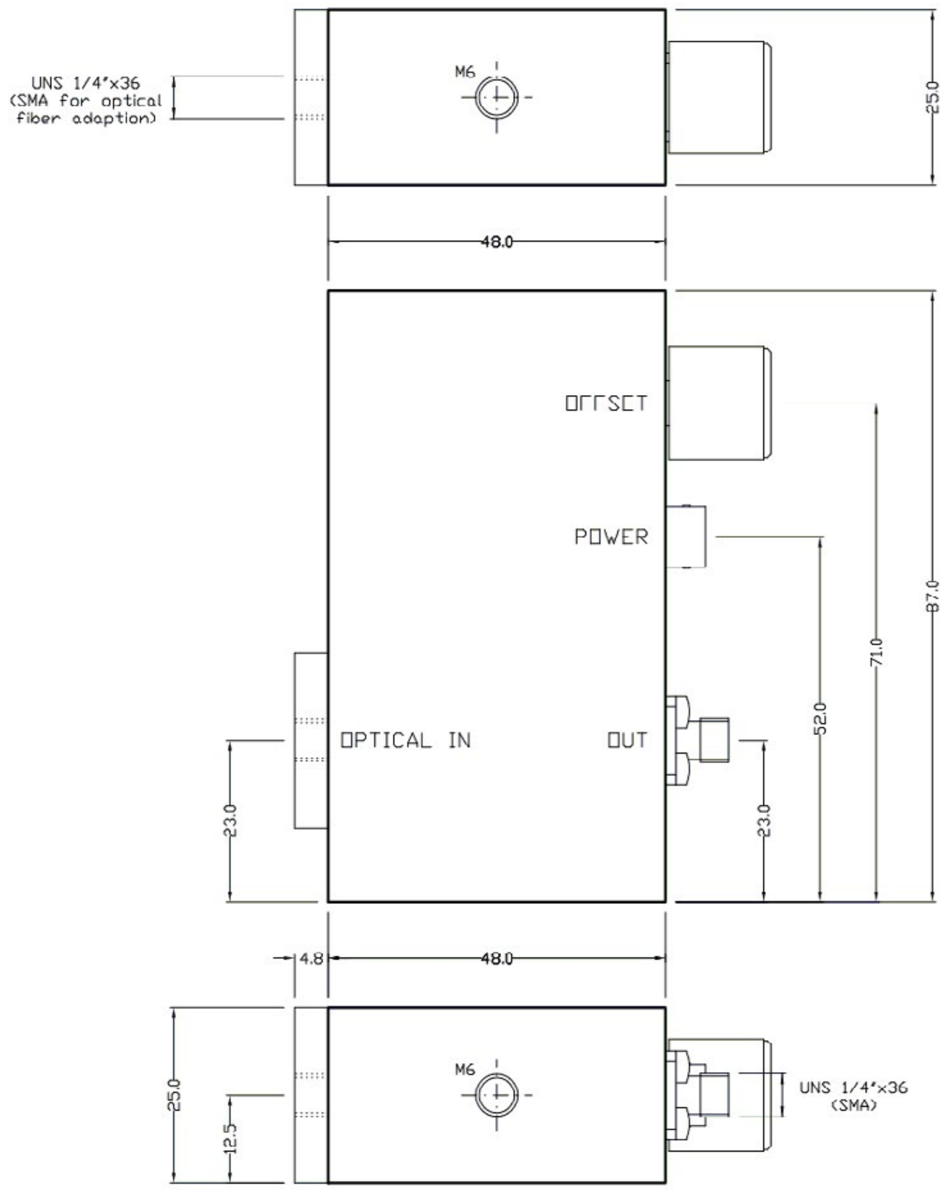

Figure 2: Case dimensions (all units in mm)

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CONNECTORS

Input	Optical, with microbench adapter (Ø 25 mm) and SMA fiber adaption
Output	SMA Connector
Power Supply	Hirose series HR10-7R-6P, 6-Pin Pin 1, 2: +Vs Pin 3, 6: GND Pin 4, 5: -Vs

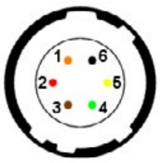

Table 1: Connectors

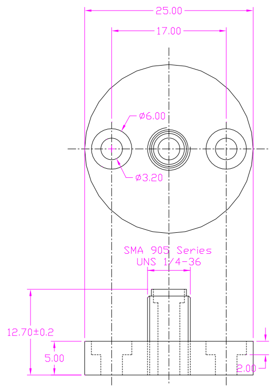

Figure 3: SMA Fiber Adapter

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RESPONSE

Standard "No Slow Tail" (NST) option

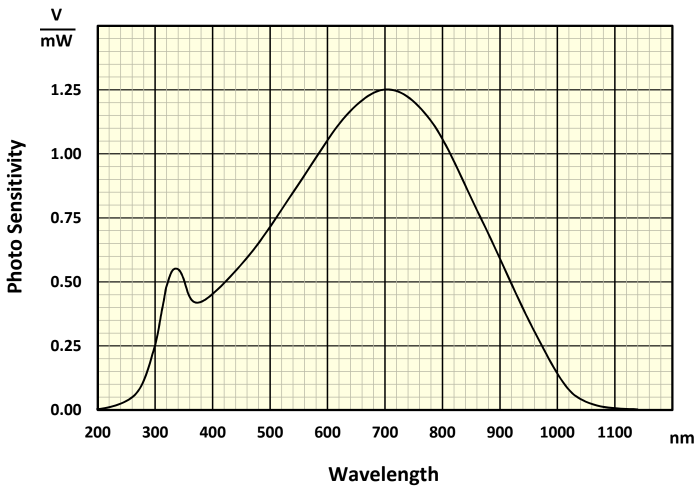

Figure 4: Spectral response (NST)

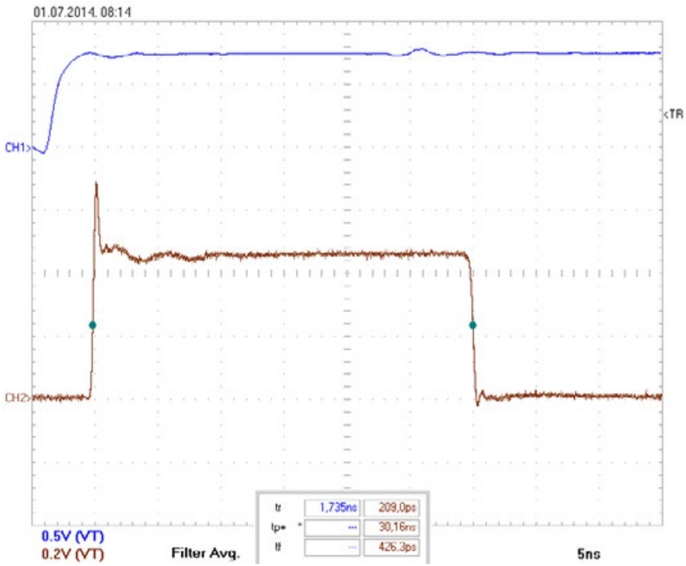

Figure 5: Pulse response (NST)

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"Near Infrared" (NIR) option

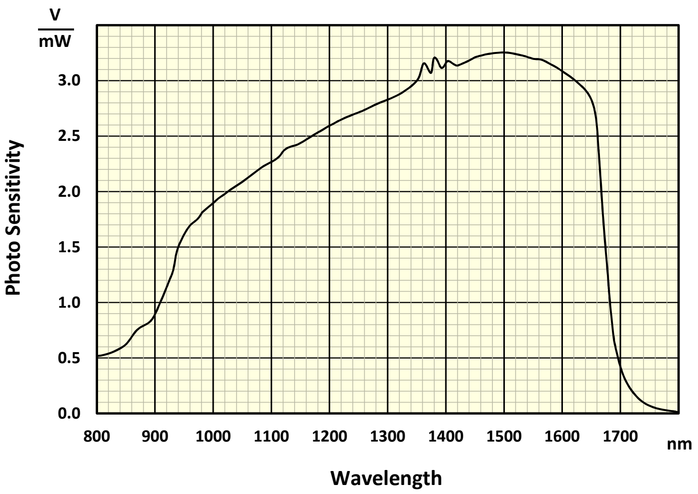

Figure 6: Spectral response (NIR)

APPLICATION NOTES

These application notes are meant to demonstrate some typical measurement tasks, carried out with the iC212 and verified with a standard optical power meter.

Mesurement of total optical output power P_{opt}

1. Put laser in pulse mode

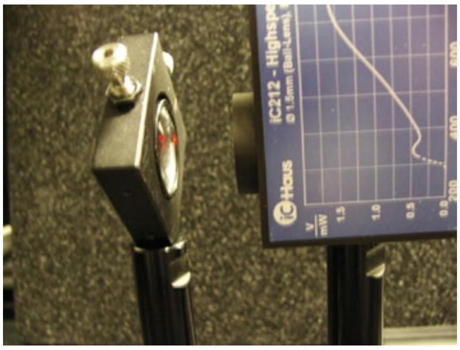

Figure 7: The laser light focused with a collecting lens onto the sensor

2. Adjust lens, for maximum amplitude at the output of iC212 (Fig. 7)

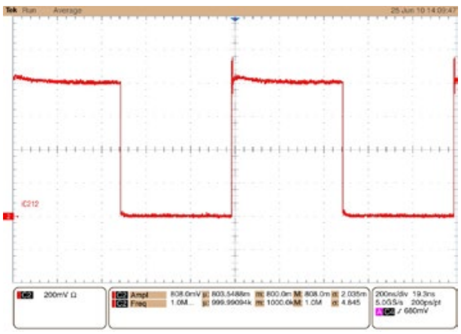

Figure 8: Oscilloscope reading

3. Read amplitude: U = 0.803 V (Fig. 8)
   Calculation: λ = 635 nm, spectral response taken from Figure 6: S(@635 nm) = 1.34 V/mW

$$P_{opt}(iC212) = \frac{U}{S} = \frac{0.803\,V}{1.34\,\frac{V}{mW}} = 0.60\,mW$$

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4. Put laser in CW mode
5. Put Newport sensor into laser beam and read the power: P_{opt}(Newport) = 0.641 mW (Fig. 9)

The results match within 7%.

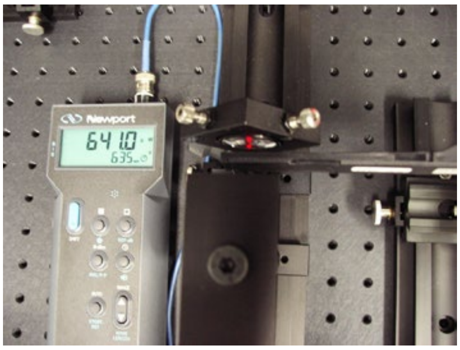

Figure 9: Total optical output power with 1 cm^2 sensor (Newport)

Measurement of Irradiance E

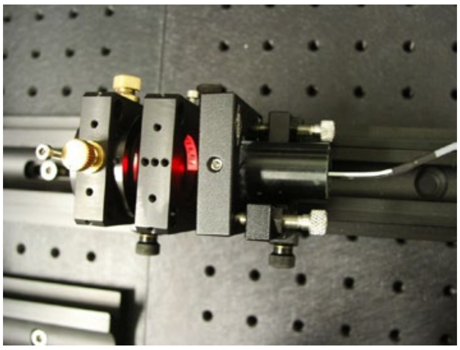

Figure 10: Laser 659 nm, 150 mW with two microlens arrays for homogenisation

1. Put laser in CW mode
2. Homogenisation of laser light with microlens arrays (Fig. 11)
3. Put iC212 into the center of the homogenised laser light (Fig. 12)
4. Read oscilloscope: U = 76 mV (Fig. 13)
   Calculation: λ = 659 nm, spectral response taken from Figure 6: S(@659 nm) = 1.42 V/mW, effective area (Item No. 302: Aeff = 0.75 mm^2)

$$E(iC212) = \frac{U}{S * A_{eff}}$$

$$= \frac{0.076\,V}{1.42\frac{V}{mW} * 0.75\,mm^2} = 0.071\frac{mW}{mm^2}$$

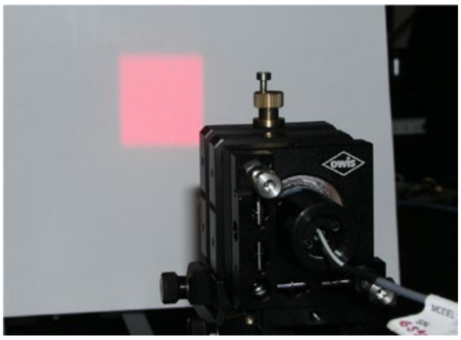

Figure 11: Homogeneously illuminated area of ca. 4 cm x 4 cm

5. Put Newport sensor into laser beam and read the power: P_{opt}(Newport) = 6.441 mW (Fig. 14)
6. With a sensor area of 100 mm^2 this results in E(Newport) = 0.0644 mW/mm^2

The results match within 10%.

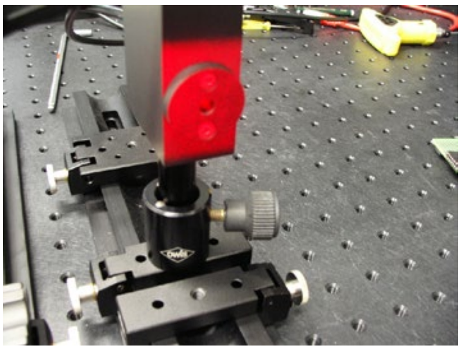

Figure 12: iC212 in the center of the homogenised laser light

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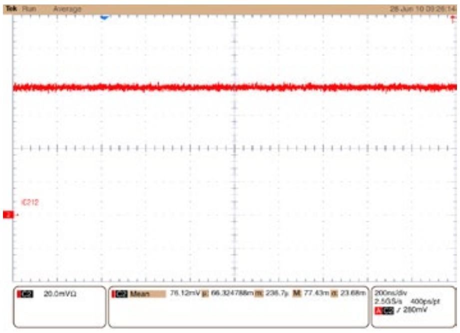

Figure 13: Oscilloscope reading

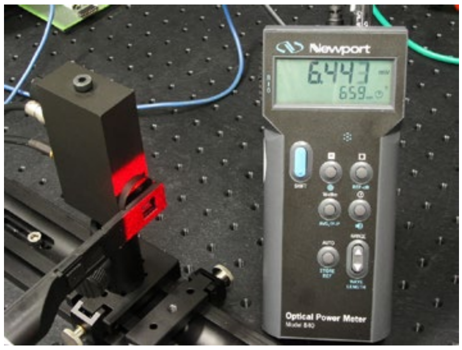

Figure 14: Newport sensor in the center of the homogenised laser light

Measuring time of flight

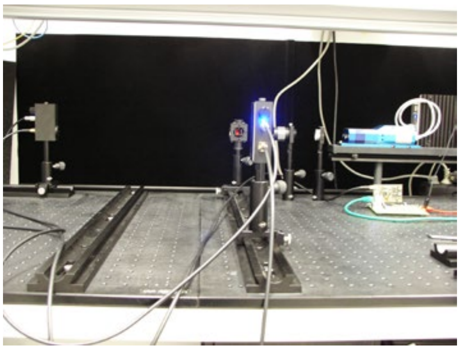

Figure 15: Laser, pole filter, beam expander, beam splitter and two iC212

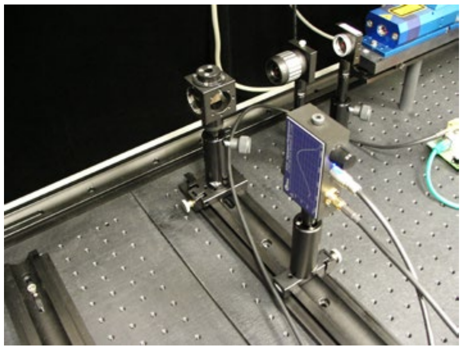

Figure 17: One iC212 positioned 30 cm closer to the beam splitter

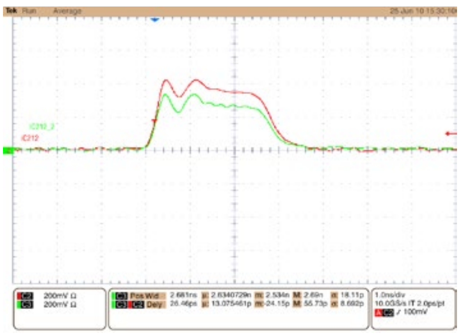

Figure 16: No propagation time difference at same distance from beam splitter

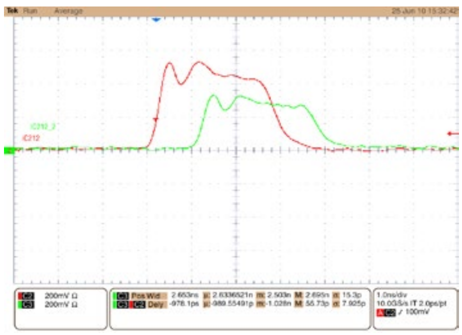

Figure 18: 30 cm distance difference means 1 ns propagation time difference

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Fiber-optic input

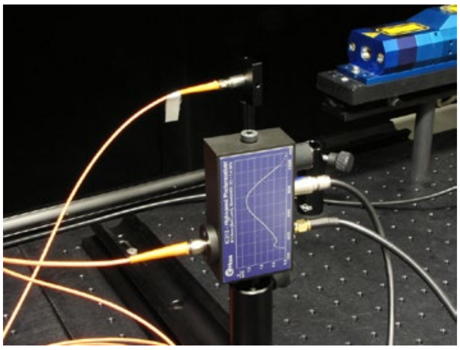

Figure 19: Laser, SMA fiber collimator, fiber, iC212 fiber adapter, iC212

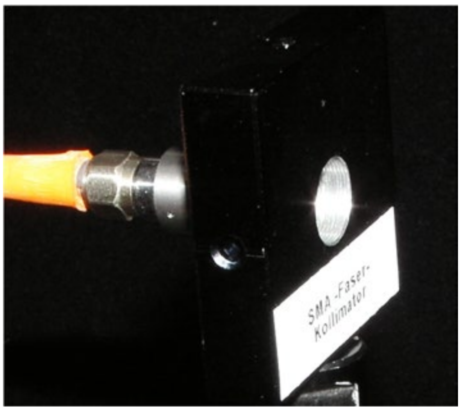

Figure 21: SMA fiber collimator

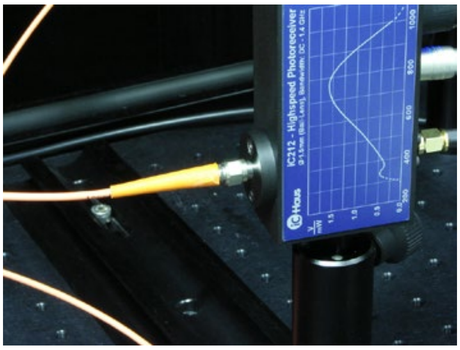

Figure 20: iC212 fiber adapter

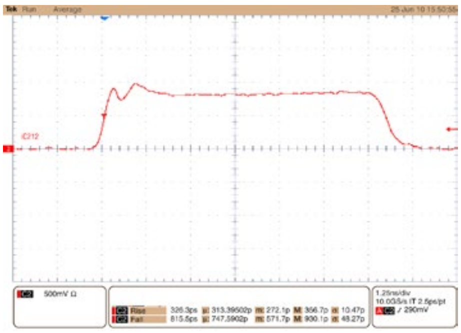

Figure 22: Fiber transmitted light pulse

Noise Equivalent Power (NEP)
NEP specifies the lowest light power (Pmin) that can be detected by the sensor. In that case the signal to noise ratio (S/N) would be 1, which means the signal to be measured is of the same magnitude as the noise.

$$P_{min}(\lambda) = \frac{S_{max}}{S(\lambda)} * NEP * \sqrt{BW}$$

$P_{min}(\lambda)$ - minimum detectable power, which can be distinguished from noise (only white noise, 1/f-noise ignored)
$S(\lambda)$ - photo sensitivity at wavelength λ
S_{max} - maximum photo sensitivity
NEP - NEP at maximum photo sensitivity
BW - bandwidth

Example
Blue LED with λ = 473 nm, square wave modulated f = 1 MHz (T = 1 µs), bandwidth of measuring circuit BW = 93 MHz.

S_{max} = 1.625 V/mW (Figure 6)
NEP = 115 pW/$\sqrt{\text{Hz}}$ (Item No. 305)
$S(\lambda = 473\,nm)$ = 0.67 V/mW (Figure 6)

$$P_{min}(\lambda = 473\,nm) = \frac{1.625}{0.67} * 115 \frac{pW}{\sqrt{Hz}} * \sqrt{93\,MHz}$$
$$= 2.7\,\mu W_{RMS}$$

This calculation is only valid, if the input noise is frequency independent. Figure 23 shows the input noise (INV = Input Noise Voltage) of the photo amplifier.

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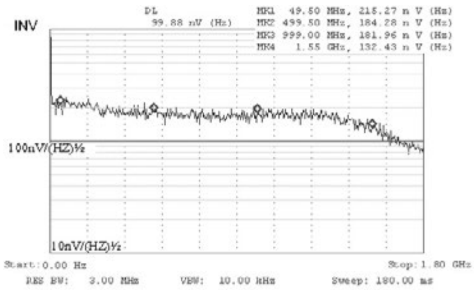

Figure 23: Input Noise Voltage as a function of the frequency - with lower frequencies there is higher noise

For frequencies around 93 MHz an input noise of 215 nV/$\sqrt{\text{Hz}}$ can be estimated.

NEP(λ) = INV(f) * 1/S(λ)
NEP(λ = 473 nm) = INV(93 MHz) / S(λ = 473 nm)
NEP(λ = 473 nm) = 215 nV/$\sqrt{\text{Hz}}$ * 1 mW / 0.67 V
= 320 pW/$\sqrt{\text{Hz}}$
Noise(BW) = NEP(λ = 473 nm) * $\sqrt{\text{BW}}$
Noise(93 MHz) = 320 pW/$\sqrt{\text{Hz}}$ * $\sqrt{93\,\text{MHz}}$
= 3.09 µW_{RMS}

As to be expected this value is slightly higher than in the first estimation.

Mesurement of minimum optical power $P_{min}(\lambda)$

1. Homogenisation of the blue LED light with microlens arrays (Figure 24)
2. LED modulation with 1 MHz
3. Change distance between iC212 and LED until signal is barely distinguishable from noise (method imprecise but rather simple to get a basic estimation)
4. Put Newport sensor at same distance as iC212 into the LED beam and read the power: PM = 126 µW (Figure 26)

Because of the duty cycle (50%), the measured power has to be multiplied by 2. The Newport sensor is completely illuminated (100 mm^2). Hence the irradiance can be calculated to

$$E(Newport) = 2 * \frac{126\,\mu W}{100\,mm^2} = 2.52 \frac{\mu W}{mm^2}$$

With the effective area of the iC212 sensor (Item No. 302, A_{eff} = 0.75 mm^2) this yield a total power of

$$P_{min}(\lambda = 473, measured) = 2.52 \frac{\mu W}{mm^2} * 0.75\,mm^2 = 1.9\,\mu W$$

This matches the calculated value reasonably well.

Output noise without signal:

$$Noise(BW) = INV(f) * \sqrt{BW}$$
$$Noise(93\,MHz) = 215 \frac{nV}{\sqrt{Hz}} * \sqrt{93\,MHz} = 2.07\,mV_{RMS}$$

A slightly higher value of µ = 3 mV_{RMS} has been measured though.

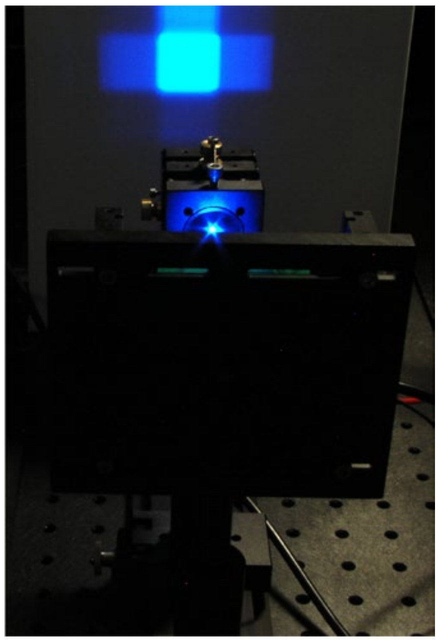

Figure 24: Homogenised blue LED light

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iC212
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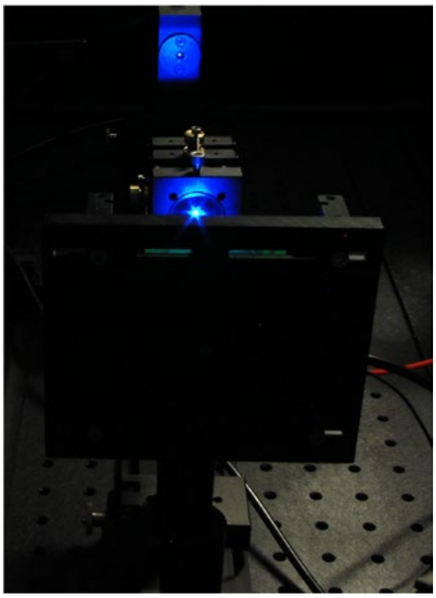

Figure 25: Homogeniously illuminated iC212

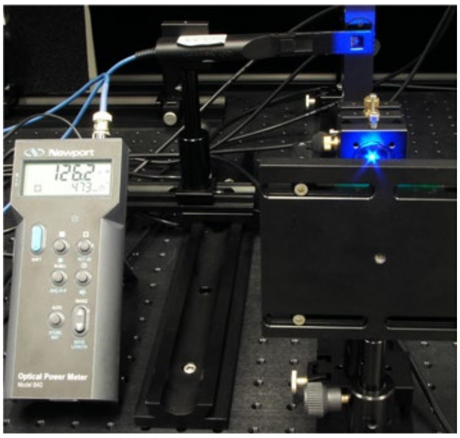

Figure 26: Homogeniously illuminated Newport sensor

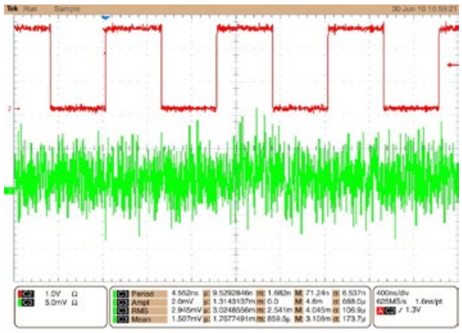

Figure 27: Noise

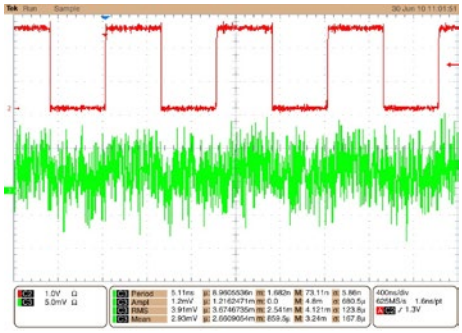

Figure 28: Noise with signal barely detectable

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Ulbricht sphere

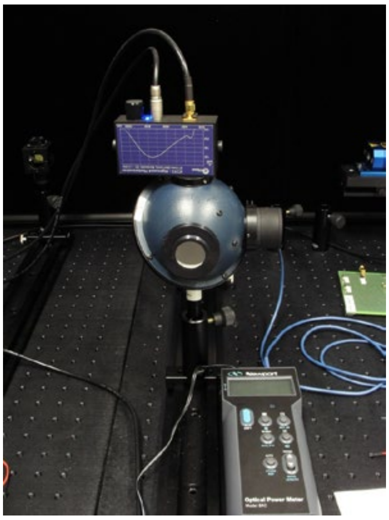

Figure 29: 3-port Ulbricht sphere with iC212 and Newport power meter

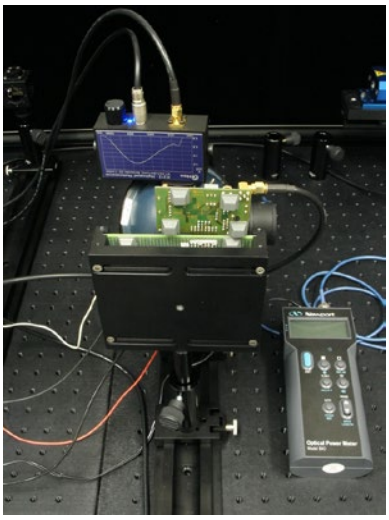

Figure 31: Laser light coupled into the Ulbricht sphere

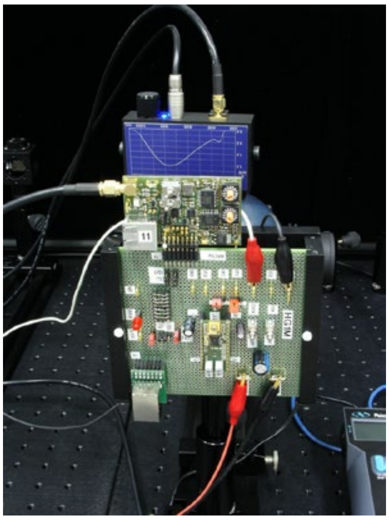

Figure 30: HG1M laser controller with 2 W CW laser diode

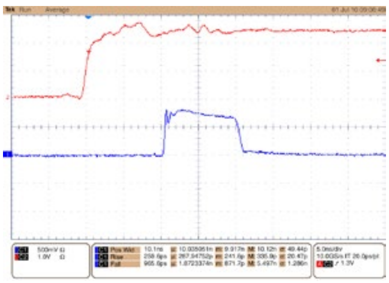

Figure 32: Laser pulse with 260 ps rise time (channel 1)

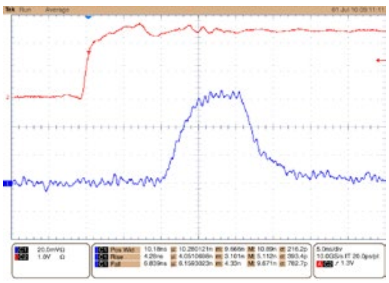

Figure 33: Due to size of Ulbricht sphere the pulse gets distorted (ca. 4 ns rise time)

On the ideal size of an Ulbricht sphere see also "How to select an integrating sphere for your application" by Valerie C. Coffey at www.laserfocusworld.com.

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iC212
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Equipment used

Mesuring instruments

Tektronix:	TDS7404B, 4 GHz, 20 GS/s, 4-Channel Digital Phosphor Oscilloscope
Newport:	Optical Power Meter Model 840
Newport:	Sensor 818-ST, Sensor 818-UV, Sensor 818-ST/CM
Newport:	819D-SL-3.3, 3-Port 3.3" Spectralon Ulbricht Sphere
Ocean Optics:	USB2000 Fiber-optic Spectrometer 320 - 1100 nm
Omicron:	LDM639.40.500, 40 mW Laser, f_{MOD} > 500 MHz
Femto:	HSA-X-S-1G4-SI, Ultra High Speed Photoreceiver
iC-Haus:	iC212 Highspeed Photoreceiver, DC to 1.4 GHz
iC-Haus:	iC227, Dual Channel 11GHz Sequential Sampling Oscilloscope
HP:	8590L, Spectrum Analyzer

Accessories

iC-Haus:	iC149, 8-Bit pulse generator ,1 to 64 ns, compatibel to LDMxxx series lasers by Omicron
iC-Haus:	iC213, 12-Bit Oszillator, 40 kHz to 500 MHz, compatibel to LDMxxx series lasers by Omicron
iC-Haus:	iC215_6, pulse-width modulator, 640 ps to 10.23 ns, compatibel to LDMxxx series lasers by Omicron and iC213
iC-Haus:	HG1M, control module for high speed, high power laser diodes
iC-Haus:	HV1M, control module for high speed, high power VCSEL arrays
iC-Haus:	HG2D, host adapter for high-speed modules

REVISION HISTORY

Rel.	Rel. Date*	Chapter	Modification	Page
B1	2015-07-30	FEATURES	NIR version added	1
		DEVICE	New standard NST version shown	1
		DESCRIPTION	NIR version added	2
		ELECTRICAL CHARACTERISTICS	NIR version added	2
		CONTENTS	New standard NST version shwon	4
		DIMENSIONS	Fiber adapter added	5
		CONNECTORS	Lens dropped	6
		RESPONSE	NIR version added	8
		APPLICATION NOTES	Equipment used: iC227, HV1M, HG2D added	15
		ORDERING INFORMATION	NIR version added	16

* Release Date format: *YYYY-MM-DD*

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LASER COMPONENTS

iC212
HIGHSPEED PHOTORECEIVER

ORDERING INFORMATION

Type	Options	Order Designation
iC212	Standard "No Slow Tail" (NST) "Near Infrared" (NIR)	iC212 iC212NIR

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