NIR-PMTs (near-infrared photomultiplier tubes) are photodetectors that provide high-speed response and high sensitivity in the near infrared region. These are ideal for detecting high-speed phenomena occurring at low light levels such as in measurements of photoluminescence, fluorescence lifetime, Raman spectroscopy, cathode luminescence, and singlet-oxygen emissions. As major NIR-PMT products, Hamamatsu offers the R5509 series photomultiplier tubes (spectral response range: 300 nm to 1400 nm or 300 nm to 1700 nm) and the H10330C series NIR-PMT units (spectral response range: 950 nm to 1200 nm, 950 nm to 1400 nm, or 950 nm to 1700 nm) that contain a thermoelectric cooler and high-voltage power supply. Either type can be used over a wide measurement range from analog detection mode to photon counting mode. This brochure introduces major applications that utilize the unique features of NIR-PMTs.

**Q. What can we do with near infrared light?**

1. Semiconductor quality control and material evaluation – Photoluminescence measurement
2. Evaluation of quantum devices and photonic crystals – Photoluminescence measurement
3. Evaluation of molecular structures – Raman spectroscopy
4. Reactive oxygen study – Singlet-oxygen emission measurement
5. Environment measurement – Light detection and ranging (LIDAR)

![THERMOELECTRIC COOLED NIR-PMT UNIT H10330C SERIES](image1)

No liquid nitrogen, No cooling water is necessary

![NIR-PMT R5509 SERIES](image2)

Wide spectral response from visible to near infrared

**Spectral response**

* C9940 series cooler is necessary for operation.
OVER VIEW

The H10330C series is the NIR-PMT unit using a compact NIR-PMT (near-infrared photomultiplier tube) developed by our advanced photocathode technology. The NIR-PMT is contained in a thermally insulated sealed-off housing evacuated to a high vacuum. The internal thermoelectric cooler eliminates the need for liquid nitrogen and cooling water. The light input window of these units use a condenser lens to provide a virtually larger photosensitive area allowing easy optical coupling. Adapters for connection to an optical fiber and monochromator are also available as options.

FEATURES

● Compact and lightweight due to vacuum sealed-off thermal insulation technology
● High sensitivity (Applicable to photon counting)
● Fast time response
  Rise time: 0.9 ns, T.T.S.: 0.4 ns
● Simple operation by air cooled TE cooler
  No liquid nitrogen, No cooling water is necessary
● Operable in 20 min after switched ON
● Large detection area
  ø18 mm for collimated light
● HV power supply with interlock function
● Optional adapters are available
  For optical fiber
  For monochromator

OUTPUT WAVEFORM

<table>
<thead>
<tr>
<th>TIME (2 ns/Div.)</th>
<th>OUTPUT VOLTAGE (20 mV/Div.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPLY VOLTAGE: -800 V</td>
<td>RISE TIME: 0.85 ns</td>
</tr>
<tr>
<td>FALL TIME: 1.65 ns</td>
<td>PULSE WIDTH: 1.63 ns</td>
</tr>
<tr>
<td>WAVELENGTH: 1300 nm</td>
<td>LOAD RESISTOR: 50 Ω</td>
</tr>
</tbody>
</table>

SELECTION GUIDE / SPECIFICATIONS

<table>
<thead>
<tr>
<th>Type No.</th>
<th>H10330C-25</th>
<th>H10330C-45</th>
<th>H10330C-75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral response</td>
<td>950 nm to 1200 nm</td>
<td>950 nm to 1400 nm</td>
<td>950 nm to 1700nm</td>
</tr>
<tr>
<td>Photocathode material</td>
<td>InP / InGaAsP</td>
<td>InP / InGaAsP</td>
<td>InP / InGaAsP</td>
</tr>
<tr>
<td>Detection area for collimated light</td>
<td>ø18 mm</td>
<td>ø1.6 mm</td>
<td>Ø18 mm</td>
</tr>
<tr>
<td>Effective area of PMT</td>
<td>ø1.6 mm</td>
<td>ø1.6 mm</td>
<td>ø1.6 mm</td>
</tr>
<tr>
<td>Cathode sensitivity</td>
<td>Quantum efficiency</td>
<td>2% Typ.</td>
<td>2% Typ.</td>
</tr>
<tr>
<td>Gain</td>
<td>1 x 10^6</td>
<td>1 x 10^6</td>
<td>1 x 10^6</td>
</tr>
<tr>
<td>Time response</td>
<td>Anode pulse rise time</td>
<td>0.9 ns</td>
<td>0.9 ns</td>
</tr>
<tr>
<td></td>
<td>Anode pulse fall time</td>
<td>1.7 ns</td>
<td>1.7 ns</td>
</tr>
<tr>
<td></td>
<td>Transit time spread (T.T.S.)</td>
<td>0.4 ns</td>
<td>0.4 ns</td>
</tr>
<tr>
<td>Main application</td>
<td>YAG laser (1.06 µm) measurement, Si Photoluminescence, Laser rader (LIDAR)</td>
<td>Singlet-oxygen emmision measurement, Si Photoluminescence</td>
<td>Optical communication device evaluation, Laser rader (LIDAR)</td>
</tr>
</tbody>
</table>
### TEMPERATURE / DARK CURRENT vs. COOLING TIME (H10330C-45)

![Temperature vs. Cooling Time Graph](image)

### SYSTEM CONFIGURATION (Connection Diagram)

- **NIR-PMT Unit**
  - **Resistor Box with BNC Connectors** (100 kΩ)
  - **High Voltage Cable** (2.5 m)
  - **Control Cable** (2.5 m)

- **NIR-PMT Unit Controller**

### DIMENSIONAL OUTLINE (Unit: mm)

**NIR-PMT Unit**

- **Fan Exhaust Vent**
  - Do not block the air intake vents and fan exhaust vent. Otherwise, heat builds up in the unit causing poor performance or failure.

- **Air Intake Vents**
  - The rubber feet are mounted with M4 screws. If they are removed, the screw holes (M4) can be used for fixing purposes.

**NIR-PMT Unit Controller**

- **Input Window**
- **Effective Area**

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*Images and labels have been extracted and transcribed for natural reading.*
**NIR-PMTs** (near-infrared photomultiplier tubes)  
(near-infrared: 1.4 μm / 1.7 μm)  
**R5509-43/-73**

### OVER VIEW

Hamamatsu near infrared photomultiplier tubes (NIR-PMT) R5509-43 and -73 have photocathodes with extended spectral response ranges to 1.4 μm or 1.7 μm where beyond 1.1 μm have been the limit of conventional photocathodes. The R5509-43 is recommended for detection up to 1.35 μm, while the R5509-73 is up to 1.7 μm. For operation, exclusive cooler C9940 series is necessary.

### FEATURES

- **High sensitivity enables accurate PL (Photoluminescence) measurement with a low excitation power that could not be obtained with a strong excitation.** High gain and low noise improve the detection limit.
- **Flat response from visible to near IR minimizes spectral sensitivity correction.** The spectral response covers a wide range from 0.3 μm to 1.4 μm or 1.7 μm.
- **Photoluminescence from a room temperature sample can be measured.** High sensitivity enables weak light emission measurement.
- **Time resolved measurement in near IR is realized.** Fast time response (Rise time): 3 ns.

* Detection limit depends on the material and measurement condition.

### OUTPUT WAVEFORM (R5509-43)

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Type No.</th>
<th>R5509-43</th>
<th>R5509-73</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral response</td>
<td>300 nm to 1400 nm</td>
<td>300 nm to 1700 nm</td>
</tr>
<tr>
<td>Photocathode</td>
<td>Material: InP / InGaAsP</td>
<td>InP / InGaAs</td>
</tr>
<tr>
<td>Photocathode</td>
<td>Minimum effective area</td>
<td>3 mm x 8 mm</td>
</tr>
<tr>
<td>Recommended operating temperature</td>
<td>-80 °C</td>
<td></td>
</tr>
<tr>
<td>Cathode sensitivity</td>
<td>Quantum efficiency</td>
<td>2 % Typ. (at 1300 nm: R5509-43, at 1500 nm: R5509-73)</td>
</tr>
<tr>
<td>Gain</td>
<td>1 x 10⁶</td>
<td></td>
</tr>
<tr>
<td>Time response</td>
<td>Anode pulse rise time</td>
<td>3 ns</td>
</tr>
<tr>
<td>Time response</td>
<td>Anode pulse fall time</td>
<td>23 ns</td>
</tr>
<tr>
<td>Time response</td>
<td>Transit time spread (T.T.S.)</td>
<td>1.5 ns</td>
</tr>
</tbody>
</table>
**RELATED PRODUCTS**

**Exclusive coolers C9940-01/-02**

The C9940-01/-02 are exclusive coolers for R5509 series photomultiplier tubes. To operate the R5509 series, it is necessary to cool it down to -70 °C to -90 °C range (recommended temperature: -80 °C). Cooling suppresses dark current and improves signal to noise ratio to make weak near infrared light measurements possible with high sensitivity.

Two types are available with different line voltage regulations, 100 V to 115 V (C9940-01) and 230 V (C9940-02).

**FEATURES**

- Temperature range: -70 °C to -90 °C
- Voltage divider, Magnetic shield case included
- Alarm with output when liquid nitrogen is running out
- No external dry nitrogen is required

**SYSTEM CONFIGURATION**

**OTHER ACCESSORIES REQUIRED**

- Liquid nitrogen container
  From 10 L to 25 L capacity
  The opening of the container should allow the 15 mm diameter liquid nitrogen suction pipe to be inserted.
- High voltage power supply
  Capable to provide stable output of -1500 V, 0.2 mA
  Recommended: C9525-02 (Supplied: High voltage cable E1168-17)
- High voltage cable with an SHV-P connector
  Recommended: E1168-17
- Signal COAX cable with a BNC-P connector
  Recommended: E1168-05
Photoluminescence measurement

Sample

**InAlAs/InGaAs**

*single quantum wells*

Photoluminescence spectra emitted from a sample with different InGaAs well widths. This data proves that intensity distribution of the spectrum corresponding to each quantum well varies with the excitation light power.

Sample structure: InAlAs/InGaAs (5QWs)/InP(sub)

**Sample Temperature** 77K

Detector: NIR-PMT R5509-73

---

Sample

**Undoped SI-InP**

Emission from deep levels in a semi-insulating InP substrate at room temperature was clearly observed.

**Sample Temperature** 300K

Sample Temperature: 77K

Detector: NIR-PMT R5509-73
Photoluminescence measurement

**Sample**

**Undoped SI-GaAs**

Emission from deep levels in a semi-insulating GaAs substrate at room temperatures was clearly observed.

**Sample**

**InAs/InGaAs quantum dots structure**

Figure shows PL spectrum at the room temperature from InAs quantum dots covered with InGaAs layer. Size and uniformity of quantum dots can be estimated from the peak wavelength and the FWHM of PL spectrum. However, when excitation power is increased, luminescence of shorter wavelength (1200 nm) becomes strong, and the estimate of exact peak wavelength and the FWHM becomes impossible.

Therefore, it is important that excitation power must be kept as weak as possible for precise measurement. For this reason, a high sensitivity detector is required.

Detector: NIR-PMT R5509-73

Detector: NIR-PMT R5509-43
**APPLICATION EXAMPLES**

### Photoluminescence measurement

#### Sample: B-Dope Si (111)

**low resistivity wafer ρ > 0.02 kΩ-cm**

Silicon, the indirect bandgap semiconductor, has lower photoluminescence emission compared with direct bandgap semiconductors such as GaAs, InP, etc. However, the NIR-PMT has made it possible to observe a clear photoluminescence spectra from a room temperature silicon wafer even at low power excitation lights.

**Detector:** NIR-PMT R5509-73

---

#### Sample: InGaAsP/InP

**Basic structure**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
<th>Carrier Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>p+ InP</td>
<td>350 µm</td>
<td>2 x 10^19 cm^-3</td>
</tr>
<tr>
<td>p+ InGaAsP</td>
<td>2 µm</td>
<td>2 x 10^19 cm^-3</td>
</tr>
<tr>
<td>p- InP</td>
<td>0.02 µm</td>
<td>2 x 10^16 cm^-3</td>
</tr>
</tbody>
</table>

An epitaxial wafer at the room temperature can be evaluated.

Photoluminescence measurement in 77 K sample is possible at low power excitation lights from a few to tens of micro-watts.

**Detector:** NIR-PMT R5509-43
Photoluminescence measurement

### Sample

**β-FeSi₂**

The NIR-PMT measures the photoluminescence of β-FeSi₂ currently being studied for use as an environmentally-friendly semiconductor material. This β-FeSi₂ sample is a silicide thin film grown by Fe-irradiation onto a silicon (111) substrate kept at a high temperature. As can be seen from the graph on the right, the photoluminescence intensity at a sample temperature of 77 K is at least 30 times higher than at 300 K. The peak wavelength of the 77 K sample occurs at 1562 nm while that of the 300 K sample shifts slightly to 1585 nm. (The longer wavelength side is limited by the photomultiplier tube sensitivity.)

Detector: NIR-PMT R5509-73

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Cathodoluminescence (CL) measurement

### Sample

**InAs/InP**

The data on the right show images of cathodoluminescence (CL) emitted from InAs islands in an InAs/InP multiple quantum well structure, observed with a scanning electron microscope (SEM) to which a light collection system and a monochromator were installed. The right-hand CL images were taken with the SEM using a Ge PIN photodiode. These images are not clear due to external noise such as cosmic rays. In contrast, the left-hand data taken with an R5509-43 photomultiplier tube shows clear, sharp CL images with a high S/N ratio. The R5509-43 allows high-sensitivity CL measurements in the near infrared region, which are expected to prove useful in optical evaluations of samples, analysis of inorganic or organic substances, and other near infrared spectroscopy.

**Cathodoluminescence (CL) measurement**

When a sample is irradiated by high-velocity electron beams, electron-hole pairs in the sample are excited and then recombine while producing a characteristic luminescence known as cathodoluminescence (CL). Information on the internal electron structures of the sample can be studied by measuring this luminescence.

**Condition**

<table>
<thead>
<tr>
<th>Electron probe</th>
<th>Accelerating voltage</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kV</td>
<td>10 nA</td>
<td></td>
</tr>
</tbody>
</table>

Detector: NIR-PMT R5509-43
Fluorescence lifetime measurement

**InAs Quantum Dots**

Data shown here is photoluminescence lifetime from InAs quantum dots grown on an InGaAs substrate, measured with time-correlated single photon counting (TCSPC) technique.

Sample: InAs Quantum Dots

<table>
<thead>
<tr>
<th>Basic structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>InAs QDs</td>
</tr>
<tr>
<td>InGaAs 15 nm</td>
</tr>
<tr>
<td>InGaAs 5 nm</td>
</tr>
<tr>
<td>GaAs buffer 300 nm</td>
</tr>
<tr>
<td>GaAs (100) substrate</td>
</tr>
</tbody>
</table>

Sample Temperature: 300K (room temperature)

*Excitation: YAG (1064 nm), Wavelength: 1274 nm
*Decay & Fitting: \( \tau_1 = 225 \text{ ps}, \ \tau_2 = 1.4 \text{ ns} \)

Detector: Detector equivalent to the H10330C-45 NIR-PMT unit

System: Near-infrared lifetime measurement system

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Fluorescence lifetime measurement

**InGaAsP**

NIR-PMTs allow making fluorescence lifetime measurements in the near infrared region. Up till now this has been difficult to measure with conventional detectors. This measurement shows the fluorescence lifetime of a compound semiconductor (at room temperature).

Sample: InGaAsP

<table>
<thead>
<tr>
<th>Basic structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>InP (0.4 µm), GaInAs</td>
</tr>
<tr>
<td>InP (0.4 µm), GaInAs</td>
</tr>
<tr>
<td>InP (0.4 µm), GaInAs</td>
</tr>
</tbody>
</table>

Sample Temperature: 300K (room temperature)

*Excitation: Nd: YAG (1064 nm)
*Fluorescent Wavelength: 1347 nm

Fit Results: \( \tau = 430.79 \text{ ns} \)

Detector: Detector equivalent to the H10330C-75 NIR-PMT unit

System: Near-infrared life time measurement system
Measurement of Raman spectroscopy

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rhodamine B in Ethanol Solution (20 µmol/L)</th>
</tr>
</thead>
</table>

Raman spectroscopy is effective in studying the structure of molecules in a solution. In particular, near infrared Raman spectroscopy enables measurement of samples which were previously impossible with conventional methods using visible light excitation because of the influence of fluorescence. In this application, clear Raman spectra of solute rhodamine B (marked by ▼) are measured, as well as a Raman spectrum of ethanol solution. This data was obtained with weak excitation light averaging 10 mW output using pulsed excitation light and gate detection method under fluorescent room lighting conditions.

**Detector:** Detector equivalent to the H10330C-45 NIR-PMT unit

Measurement of singlet oxygen

<table>
<thead>
<tr>
<th>Sample</th>
<th>Singlet oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rose Bengal in pure water</td>
<td></td>
</tr>
</tbody>
</table>

Using the R5509-43 and a pulsed laser, singlet oxygen emission with a peak at 1270 nm were efficiently detected by signal processing with a gated pulse counter, reducing effects of fluorescence. (Data obtained by CW YAG laser excitation is also shown in the same graph for comparison.)

The graph on the right shows detection limits evaluated by changing the concentration of the photosensitizer Rose Bengal. This proves that emissions from singlet oxygen of low concentration, even only 1 nmol/L, can be detected.

**Detector:** NIR-PMT R5509-43
Measurement of singlet oxygen

**Sample**

**Singlet oxygen**

Rose Bengal in acetone, methanol and water

Lifetime characteristics and emission spectrum of the singlet oxygen when the photosensitizer Rose Bengal was dissolved in acetone, methanol and water were measured.

Singlet oxygen lifetime can be measured with high accuracy, by using gated photon counting techniques that utilize high-speed response of a near infrared PMT and allow continuous scan of signal pulses obtained in a short gate time (sampling time).

In solvents which singlet oxygen has a long life, there is little singlet oxygen that thermally disappears so more singlet oxygen disappears during the emission process. This results in an increase in the entire emission level.

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**Sample**

**5-ALA (Photosensitizer)**

In photodynamic therapy (PDT), singlet oxygen plays an important role in killing tumor cells. Changes in the amount of generated singlet oxygen can be observed at the cellular level. This implies that monitoring the singlet oxygen is the key to setting optimal PDT laser irradiation conditions.

Accurate measurements can be made since NIR-PMT units can directly capture weak singlet-oxygen emissions (1270 nm) from cells.

**Experimental conditions**

Photosensitizer: 5-ALA  
Cancer cells: Rat brain tumor cells 9L  
Excitation light: 635 nm

Data courtesy of:  
Jurichy Yamamoto, Department of Neurosurgery, University of Occupational and Environmental Health, Japan  
Toru Hirano, Photon Medical Research Center, Hamamatsu University School of Medicine, Japan

Detector: Detector equivalent to the H10330C-45 NIR-PMT unit

---

**Sample**

**5-ALA (Photosensitizer)**

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Detector: Detector equivalent to the H10330C-45 NIR-PMT unit