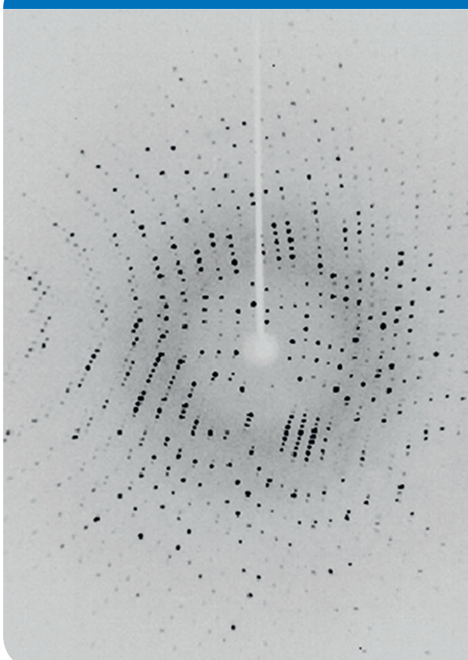
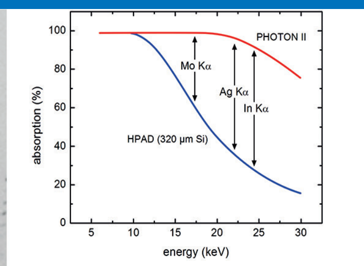
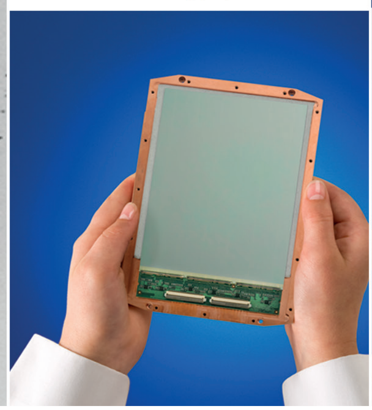






Product Sheet SC-XRD 54

PHOTON II 7 and PHOTON II 14 – CPAD Detector Series

- Size, Sensitivity and Speed: A Hat Trick for Your Success!

When you perform experiments at advanced 4th generation X-ray Free-Electron Laser (XFEL) sources, you expect cutting-edge detector technology. So why settle for less in your home laboratory? Meeting today's challenges in crystallography – where weakly-diffracting samples are the rule rather than the exception – requires the same advanced detector technology. Now, this XFEL technology is available for the home laboratory: Charge-Integrating Pixel Array Detectors (CPADs). The PHOTON II detectors feature an unprecedented combination of large, active area, quantum-limited sensitivity, and high speed. These features allow the PHOTON II series to acquire high quality data in the shortest possible time.

PHOTON II 7 and PHOTON II 14: The Double Hit in Charge-Integration Pixel Array Technology.

Figure 1: The PHOTON II 7 and PHOTON II 14 use the same CPAD detector technology as 4th generation X-ray Free-Electron Lasers (XFELs).

PHOTON II – The Revolution Continues

Bruker's introduction of the first CCD detectors in 1993 revolutionized crystallographic data collection. The second revolution followed in 2011 with the PHOTON 100's Complementary Metal Oxide Semiconductor (CMOS) technology which, for the first time, allowed shutterless, dead-time-free data acquisition in the home laboratory.

Now, with the introduction of the PHOTON II series (Figure 1) Charge-Integrating Pixel Array Detector (CPAD), the revolution continues. The PHOTON II CPAD series takes home lab detector technology to a completely new level with the largest monolithic active area, the highest Detective Quantum Efficiency, the highest speed, and the highest dynamic range. These advances dramatically improve both productivity and data quality. The PHOTON II is the only charge-integrating pixel array detector available for home laboratory use and it is ideal for crystallography's most demanding requirements:

Best data quality

- Highest detection efficiency over a broad energy range
- Best uniformity and no dead gaps
- No charge sharing noise
- Ultra-low parallax errors
- Non-destructive readout
- Patented adaptive oversampling

Fast and efficient data

- Largest monolithic sensor area compared to HPAD/HPC detectors
- Ultra-fast readout
- Shutterless data collection
- Digital signal processing unit (DSP)
- No count rate saturation

Low maintenance

- Air-cooled
- Completely sealed
- No dry purge gas

PHOTON II 7 – Size and Sensitivity

Conventional home laboratory pixel array detectors (such as HPCs and HPADs) deliver high sensitivity for Cu-radiation only, but this comes at a terrible price: the detectors are significantly smaller than previous generations. This is unfortunate because perhaps the greatest sin an X-ray detector can commit is throwing away X-rays – every reflection that misses your detector is utterly wasted. With our PHOTON II 7 detector you don't need to sacrifice size for sensitivity: you can have it all. The PHOTON II 7 features a monolithic pixel array sensor with an active area of 7 × 10 cm², more than 20% larger than typical HPC and HPAD versions.

PHOTON II 14 – Even Larger Size

The PHOTON II 14 incorporates the largest available pixel array sensor with an active area of 10 × 14 cm² (Figure 2). This allows to collect more valuable reflections that may otherwise get lost with a conventional HPAD or HPC. In short: two times larger active area compared to PHOTON II 7, still monolithic, still best uniformity, and still no gaps.

The PHOTON II family: better data, faster.

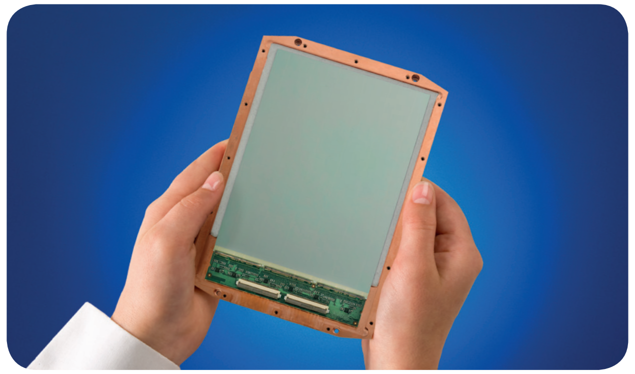


Figure 2: The PHOTON II 14 CPAD features an active area of 10 × 14 cm².

PHOTON II – See the World Clearly for the First Time

One of the prominent features of Hybrid Pixel Array Detectors (HPAD/HPCs) is that they can detect single photons. However, what is less often understood is that, in a conventional HPAD/HPC, many of the photons that hit the detector are never detected at all – they are simply lost. As noted above, this is due in large part to the relatively small active area and the gaps of home laboratory HPAD/HPCs.

However, there are other additional effects which lead to significant signal losses: incomplete absorption of X-rays in the detector and charge sharing.

PHOTON II – Don't Let Half of Your X-rays Get Away!

Conventional HPAD/HPC detectors use silicon as the detection element. Silicon is in many ways a wonderful material, but it was never meant for X-ray detection. Its relatively poor X-ray absorption means that, at higher energies, more than half the X-rays hitting the HPAD/HPC pass through the sensor and are thus never detected at all, even for the thickest available sensors.

In contrast, the PHOTON II series uses an advanced sensor with a high X-ray detection efficiency over the entire energy range, more than twice the efficiency of a silicon HPAD/HPC for Ag-Kα radiation.

The PHOTON II Puts All Your X-rays Where They Belong

The low absorption efficiency of silicon also causes parallax, in which X-ray counts are assigned to the incorrect pixel (essentially smearing the Bragg reflections in the radial direction). In a conventional silicon HPAD/HPC, the parallax error can be more than a millimeter for Mo radiation! Parallax can therefore cause overlapping of reflections for large unit cells or of satellite reflections from modulated structures. These smeared reflections also lead to higher integrated noise.

Because of this limitation, advanced CPAD detectors recently developed for XFELs and synchrotrons operate with high-density sensors to improve DQE and reduce the parallax effect for high-energy radiation. The PHOTON II generation offers this same capability and is thus able to achieve negligible parallax error up to the highest energies of interest in the typical home lab (<1 pixel parallax for Ag-Kα).

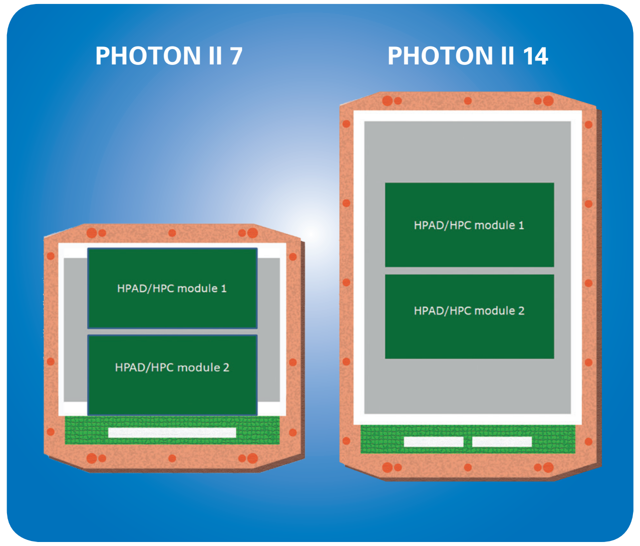


Figure 3: PHOTON II's large monolithic sensors compared with typical HPAD/HPC modules. The relatively small size of the HPAD/HPC modules necessitates imperfect tiling which leaves gaps in the image.

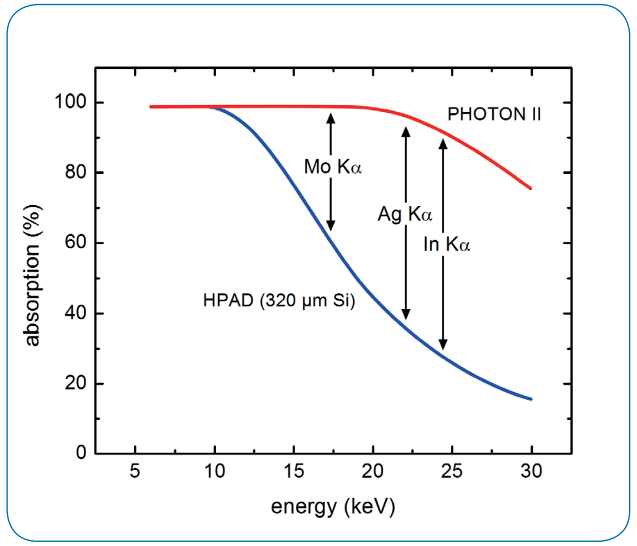


Figure 4: Conventional HPAD/HPCs suffer from poor absorption at high energies. Thus, for Ag-Kα radiation for example, more than half the X-rays are not detected at all. The PHOTON II family features high efficiency across the entire energy range typically used in crystallography.

CPAD Technology

Non-Destructive Readout (NDR): See Your Data in a Completely New Way

As the old saying goes, the wise carpenter measures twice, and then cuts once. The PHOTON II takes this wisdom to the next level.

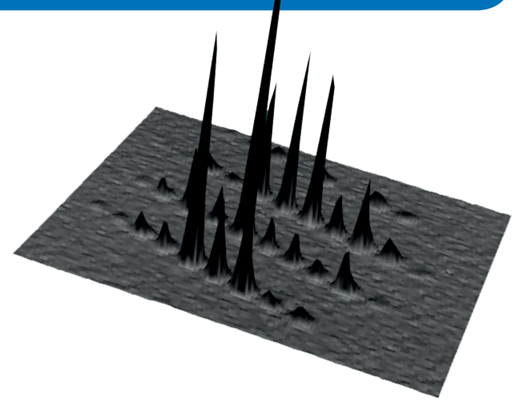
Conventional sensors measure the charge in a pixel, and – in the process – the charge is destroyed. This means that the errors in the pixel readout are "cast in stone" as the information that was stored in the pixel is gone forever.

However, the PHOTON II has the unique capability to read the charge in a pixel many times without destroying or disturbing the charge (Non Destructive Read-out). By repeatedly measuring the pixel charge, we can dramatically improve data precision and accuracy – just like the wise carpenter.

This unique feature makes the PHOTON II the detector of choice for the most demanding applications such as charge density studies or the investigation of weakly-diffracting proteins.

Adaptive Oversampling (AO): Improve Dynamic Range to the Nth Degree

Non-Destructive readout may also be employed to extend the dynamic range of a charge-integrating pixel array detector. Correlated Double Sampling (CDS) has long been used to improve the dynamic range in conventional detectors. In this simple mode, each image is effectively read out twice which consequently improves the dynamic range by up to a factor of two. With the PHOTON II, Bruker extends this concept with the newly developed, patented Adaptive Oversampling (AO) mode, matching detector operation to the diffraction properties of the sample. This is essentially an extension of the correlated sampling algorithm that takes advantage of the PHOTON's unique ability to acquire many non-destructive exposures. Multiple high-speed Non-Destructive Read-outs are combined using advanced algorithms, resulting in greatly extended dynamic range far beyond the factor of two possible with simple double sampling.



Sharing is Good, Except in a Detector!

The other effect that leads to X-ray losses in an HPAD/HPC is perhaps even more insidious: charge sharing.

A useful analogy is that using a conventional HPAD/HPC is like looking at the world through a window screen. That is, the screen mesh partially obstructs one`s view. Exactly the same effect occurs in a conventional HPAD due to charge sharing.

An HPAD/HPC does not count X-rays directly. Rather, it counts the cloud of electron charge produced when an X-ray is absorbed by the silicon sensor. When an X-ray hits near the boundaries between adjacent pixels, the resulting charge is divided between those pixels. This reduces the signal and causes counts to be lost. That is, a conventional HPAD/HPC has an insensitive dead frame around each pixel, and every reflection that hits one of these insensitive areas is compromised. This causes an error in intensity measurements that is not correctable.

To address this weakness of the HPAD/HPCs, the new Charge-Integrating Pixel Array Detector technology (CPADs) has been developed. CPADs preserve the speed and sensitivity advantages of the older HPAD/HPC designs while completely eliminating charge sharing. They do this by measuring the integrated charge in each pixel with very high accuracy. Consequently, no information is thrown away.

With the PHOTON II, every single X-ray is carefully detected.

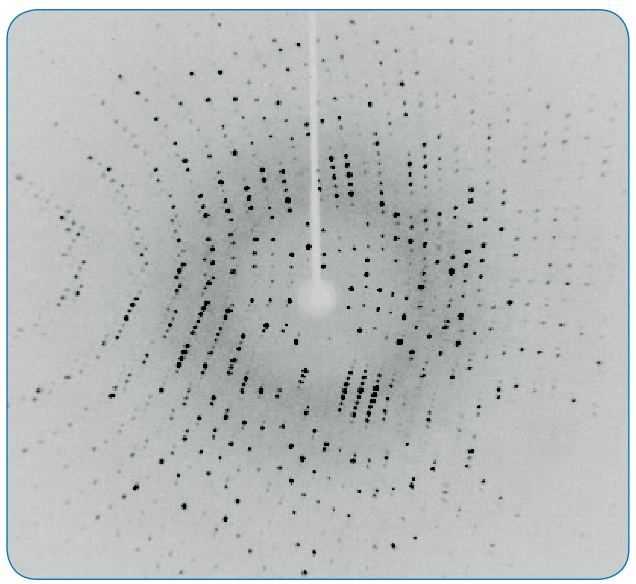


Figure 5: The diffraction image of Lysozyme shows the high spatial resolution and high sensitivity of the PHOTON II.

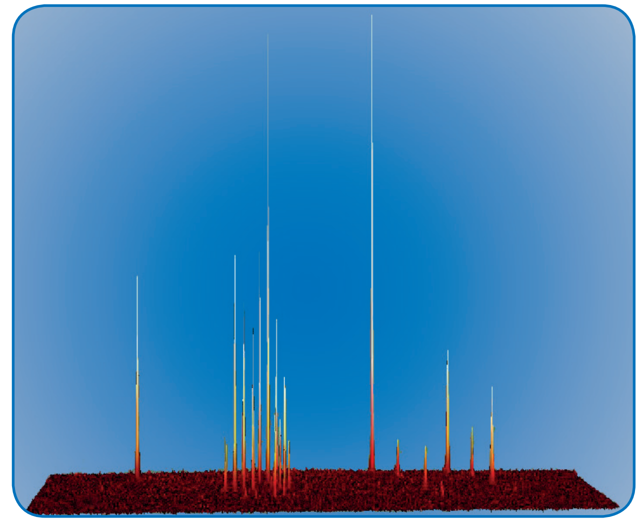


Figure 6: 3-D view of a diffraction image of a transition metal complex (3 seconds exposure).

Without Count Rate Limitations – CPAD Technology

For strong reflections, conventional HPAD/HPCs also suffer from count rate saturation. For example, typically non linearity on the order of 10% is seen at count rates on the order of 10^6 counts per second per pixel. This nonlinearity must be corrected in software, which is only possible to a limited extent.

CPADs do not suffer from this saturation effect. This is one of the primary reasons for applying CPAD technology at next-generation XFEL sources.

The PHOTON II is able to achieve sustained count rates of up to 10^6 counts per pixel per second with no count rate nonlinearity. This makes the PHOTON II the detector of choice.

Shutterless Mode: Unprecedented Acquisition Speed and Data Quality

The PHOTON II detector family features super-fast 70 Hz frame readout as well as zero dead time between frames. The PHOTON II imager permits data to be read out while the camera is exposed to X-rays. This eliminates the need to close and re-open the X-ray shutter and to stop, reposition and re-start the goniometer during data collection. In turn, the sample can be continuously exposed to X-rays while it is continuously rotated, which completely eliminates shutter jitter and goniometer irreproducibility – a major source of noise in traditional systems.

PHOTON II – Advanced Signal Processing for the Best Data Quality

Innovative data modes such as Non-Destructive Readout and Adaptive Oversampling demand intensive real-time processing capabilities. For this reason, the PHOTON II incorporates a powerful Digital Signal Processing (DSP) unit that accomplishes the massive computations required for these advanced data modes in real time.

The DSP allows the PHOTON II to achieve the highest data quality while simultaneously preserving all the compelling benefits of shutterless data acquisition.

PHOTON II – The Bottom Line

By bringing XFEL detector technology into the home lab, the PHOTON II series delivers unparalleled performance.

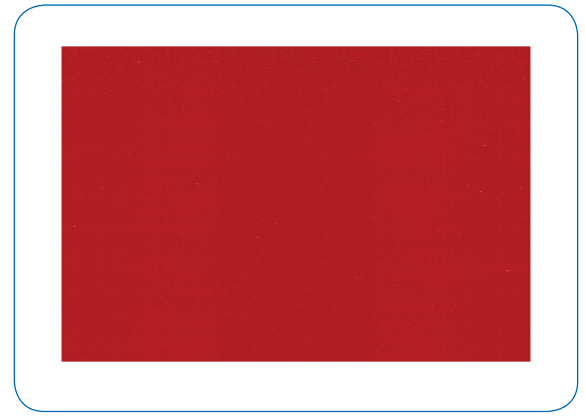


Figure 7: A 30 second dark image from the PHOTON II 7 shows essentially zero-noise aside from small signals due to natural radioactivity.

PHOTON II – Wrap-Up

Efficiency The PHOTON II features an active area of 70 cm² or 140 cm², allowing data sets with higher data multiplicity in shorter time compared to other in-house detectors.	**Extended dynamic range** Adaptive Oversampling (AO) extends the detector's dynamic range for strong signals but, even more importantly, for weak signals.
Future proof Charge-Integrating Pixel Array Detectors are the latest technology that is also used for current XFEL detector development.	**Low maintenance** The air-cooled, temperature-stabilized PHOTON II detectors require neither internal cooling water nor dry purge gas.
Best data quality CPADs have high linearity even at the highest count rates and do not suffer from charge-sharing effects like hybrid pixel detectors.	**Versatility** The PHOTON II is optimized for multi-wavelength applications from Cu Kα to In Kα.
Highest sensitivity The unique combination of non-destructive readout (NDR) and destructive readout (DR) achieves quantum-limited sensitivity.	**Full integration** The PHOTON II is fully integrated in our D8 QUEST ECO*, D8 QUEST and D8 VENTURE solutions, with the highest-intensity laboratory sources available.

*PHOTON II 7 only

Technical Specifications

Detector Type	Charge-Integrating Pixel Array
Active area (mm)	PHOTON II 7 104 × 69 PHOTON II 14 104 × 139
Number of modules	1
Sensor format (pixels)	PHOTON II 7: 512 × 768 PHOTON II 14: 768 × 1,024
Pixel size (microns)	135
Total dead area (%)	0
Percentage of active area with charge sharing losses (%)	0
Count rate nonlinearity (% at 10^6 X-rays per pixel-sec)	0
Maximum parallax error (pixels)	<1 for Cu, Mo, Ga, In, Ag radiation
Sensor dynamic range	>200,000
Readout time (full frame, msec)	14
Readout dead time between frames (msec)	0
Operating energy range (keV)	5-30
Single photon detection confidence (Cu Kα to In Kα)	>0.95
Readout mode	Adaptive oversampling with non-destructive readout
Operation mode	Shutterless
Cooling	Air-cooled

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