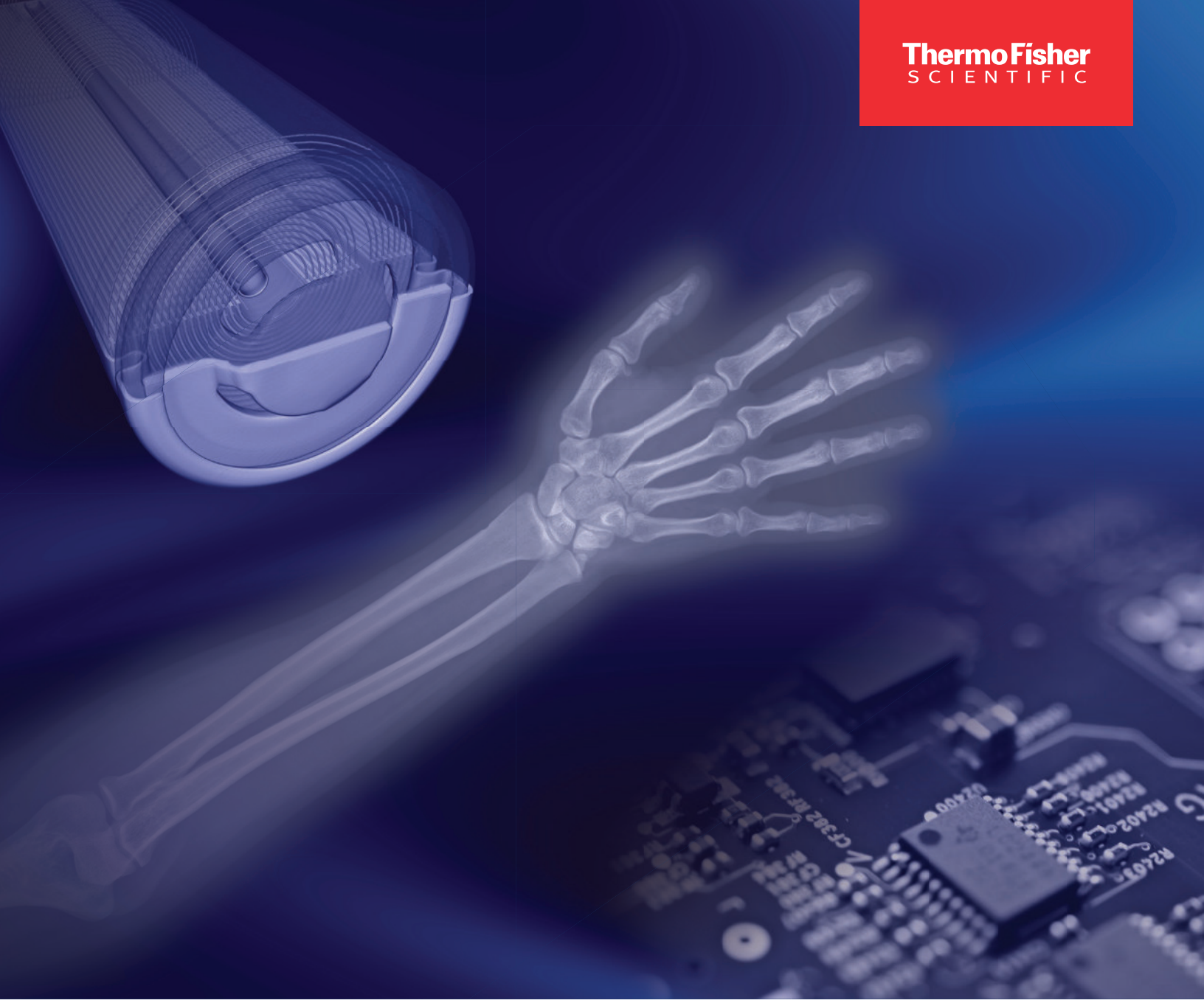

ThermoFisher SCIENTIFIC

# Thermo Scientific X-Ray Sources:

## Flexible and robust performance for industrial and medical imaging applications

thermo scientific

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# Superior imaging solutions

X-ray sources are deployed in a wide range of applications, for the testing, imaging, and inspection of items ranging from batteries, printed circuits boards and semi-conductor devices to animal fluoroscopy and dental prosthetics quality control. Our portfolio of x-ray sources includes 4 distinct model families, with multiple variants offering the flexibility to closely match source performance to specific requirements.

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# Making a sound choice: Factors that count when it comes to x-ray source selection

X-rays are particles that have sufficient energy to ionize atoms and disrupt molecular bonds, therefore a form of ionizing radiation. X-rays exist in the electromagnetic spectrum between UV and gamma rays, corresponding to high energy and short wavelength and enable us to penetrate a wide range of materials. X-ray penetration has proven to be especially useful for radiopaque imaging in medical applications to observe bones and soft tissue. There are a vast number of techniques and applications that use x-ray interaction for spectroscopy and analysis of matter. Unlike radioisotopes, x-ray sources can be powered on and off at will, thus eliminating any potential for harm when not in use.  Other advantages - including cost - underpin the widespread use of x-ray systems. Deployed on-, at- and off-line, they are relied on for the testing, imaging, and inspection of items ranging from batteries to bones.

## How do x-ray sources work?

X-ray sources come in many different designs, but most share the same basic principles of operation. The simplistic x-ray tube contains a cathode and anode within a sealed glass vacuum envelope. This configuration is known as a “diode” and utilizes the applied voltages and geometry to achieve the desired x-ray performance. The cathode is located in what is termed, the electron gun. In higher performance x-ray sources the electron gun has a plurality of electrodes to shape the electron beam that is produced and projected towards the anode, enabling generation of smaller x-ray focal spot sizes in the micron range. This is known as microfocus x-ray performance.

**An example of the x-ray tube operaton is as follows:**

A cathode is heated to a temperature sufficient for electrons to escape in the presence of a miniscule voltage applied near the emission surface by virtue of the work-function of the cathode material (Ex: Tungsten = 4.5 eV). This process is known as thermionic emission. The cathode material determines the emission

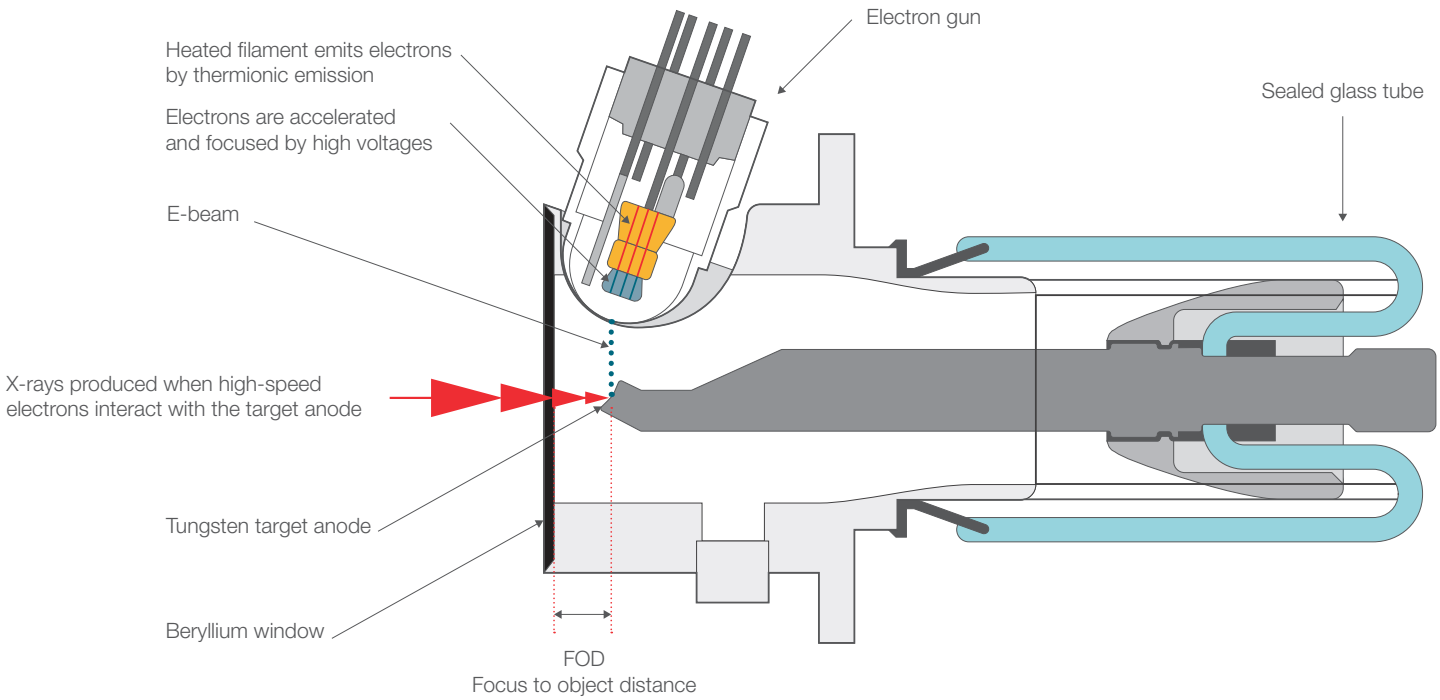



**Figure 1.  Layout diagram of a microfocus x-ray tube.**

current density (brightness). Lower work function and higher current density translate to higher performance of the x-ray source, especially in terms of power and smaller focal spot. The electron gun accelerates the beam uniformly through a path which is focused precisely onto the surface of the target anode. The voltage applied to the anode determines the x-ray energy and the combination of voltage and current determine the total power and flux intensity of the x-rays being produced. The “focal spot” at the surface of the target anode is a combination of the electron beam footprint and the x-ray volume interaction (scattering). The electron beam is intentionally defocused to prevent the power density from increasing the temperature of the target surface to a point that will melt the target material. For a tungsten foil target this temperature would be in excess of 3400 degrees Celsius.

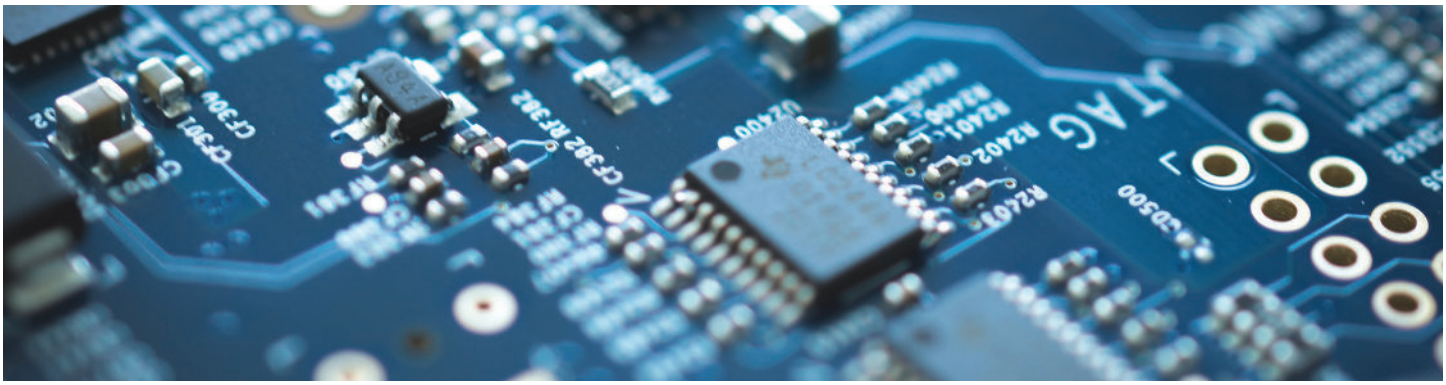
Our high-performance x-ray sources incorporate sealed micro-focus x-ray tubes with beryllium windows. Let’s unpack what that means in terms of practical benefits.

- Sealed glass vacuum envelopes: Compared to open-pumped x-ray tubes, our designs are typically associated with robust uptimes and continuous operation

- Micro-focus performance: Our x-ray tubes are designed with high geometric magnification and configured to maximize power into the smallest focal spot obtainable. This enables our customers the highest resolution imaging possible with minimal blur.

- Beryllium window interface: Durable brazed hermetic assemblies that are exceptionally transparent to x-rays making them the optimal choice for high performance sealed systems.

X-rays interact with matter in two principal ways: absorption and scattering. Absorption is the dominant mechanism and is based on the probability an x-ray photon will travel or be attenuated to transfer all the particle energy. Scattering is the probability of partial effects which can be elastic (Rayleigh) or inelastic (Compton). Customers that image take advantage of the known laws of physics and x-ray interaction with materials to optimize the non-destructive testing applications they require. For example, in medical imaging, the attenuated x-rays in combination with scattered x-rays determine the contrast and detail revealed between soft tissues. The projected image of the soft tissue is often recorded at lower magnifications. Whereas a microprocessor has components and design rules that require the highest magnification and replication of the 3D x-ray image re-construction to reveal critical to quality defects on the smallest order of hugely varied material densities. Furthermore, when dense materials such as EV battery cells are under test, x-ray penetration and intensity become hugely important to detect small internal defects. Optimized x-ray energy/ voltage and power are paramount to application goals.



# The practical implications of source specifications

**Maximum voltage:** The primary specification for source comparison is the maximum voltage of the x-ray source. Higher x-ray energy translates to lesser limitations of x-ray penetration for a given application.

**Maximum power:** The maximum power determines the limitations of x-ray flux intensity and thus hugely impacts the detected signal, acquisition time, and noise. The maximum power is proportional to the maximum current that can be produced for a given voltage/energy of the x-ray source.

**Spot size:** Focal spot size is limited by the power and energy across the range of x-ray source operation. The absolute minimum spot size enables the highest resolution imaging which is typically achieved at the lower power range throughout the range of operation. The focal spot predictably increases in size with increasing power. Exceptional focal spot performance is best realized by using high geometric magnification.

**Geometric magnification (FOD):** The ability to obtain close coupling of the object or device under test to the origin of the x-ray produced is termed FOD or Focus Object Distance. The shorter the FOD the higher the possible geometric magnification. This is especially important for the highest resolution imaging of the smallest geometries that can be examined. Magnification will reveal the smallest x-ray focal spot limitations by virtue of the magnified blur at the edges of the object being imaged. Most of our micro-focus product lines take advantage of the shortest FOD possible for a given maximum voltage that can be applied to the target anode.

**Cone of illumination:** The x-ray cone of illumination represents the available flux intensity steradian distribution and considers the target anode angle intersection to the beryllium window exit as a limiting factor. Many of our sources offer uniform cone angles as opposed to asymmetric illumination. The widest available cone of illumination allows end users to take advantage of off-axis imaging, wide field of view, and increased number of objects that can be tested at a single exposure. Many users prefer a smaller cone of illumination obtained through collimation. Furthermore, a shallow target anode angle may allow for a slight decrease in minimum focal spot that can be achieved. This target to focal spot relationship is what is known as the “compression axis” and is proportional to the sine of the target angle as viewed center-axis of the target anode post and beryllium window. The orthogonal axis to the target compression is known as the non-compression axis. Users should be aware of focal spot distortion from center-axis to the edges of the FOV. Likewise, there is a predictable distribution of flux intensity that changes from center-axis to the edges of the FOV. We manufacture both narrow and wide field cones with uniform-round geometry to allow for the source to be positioned at different angles and maintain the same X-ray illumination. This gives users the freedom and agility to manipulate our sources for a wide range of application needs.

FOD: Field of view
FOD: Focus to object distance
FDD: Focus to detector distance
Penumbria: Image blur observed at edges of subject

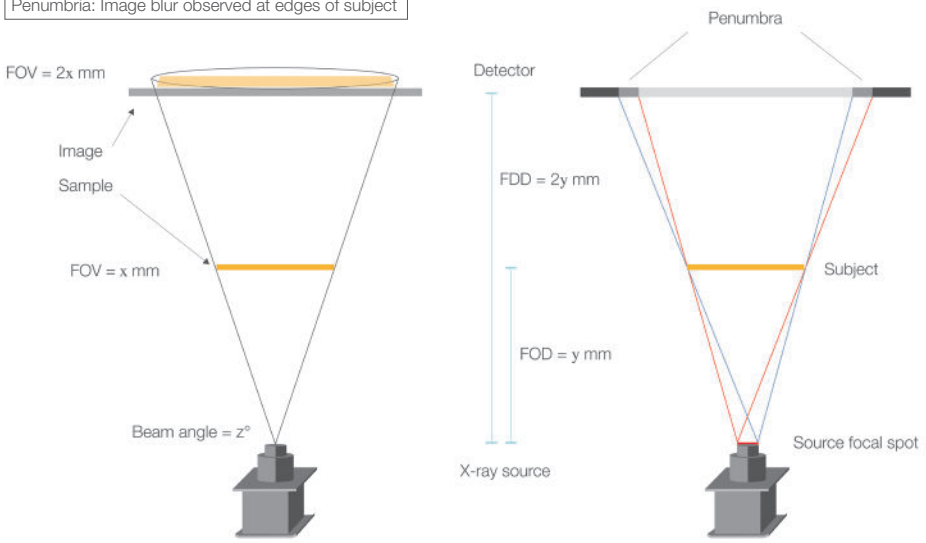



**Figure 2. Geometric magnification (left) and image blur (right) shown in an example imaging set-up where the subject under inspection is equidistant between source and detector.**

# The right source for each application

Four distinct models make-up our x-ray source portfolio with multiple variants offering further flexibility to closely match source performance to specific requirements. By industry standard, micro-focus x-ray source are defined by the ability to achieve a minimum focal spot between 1 um and 100 um FWHM (Full width at half maximum). All our product lines achieve microfocus performance.

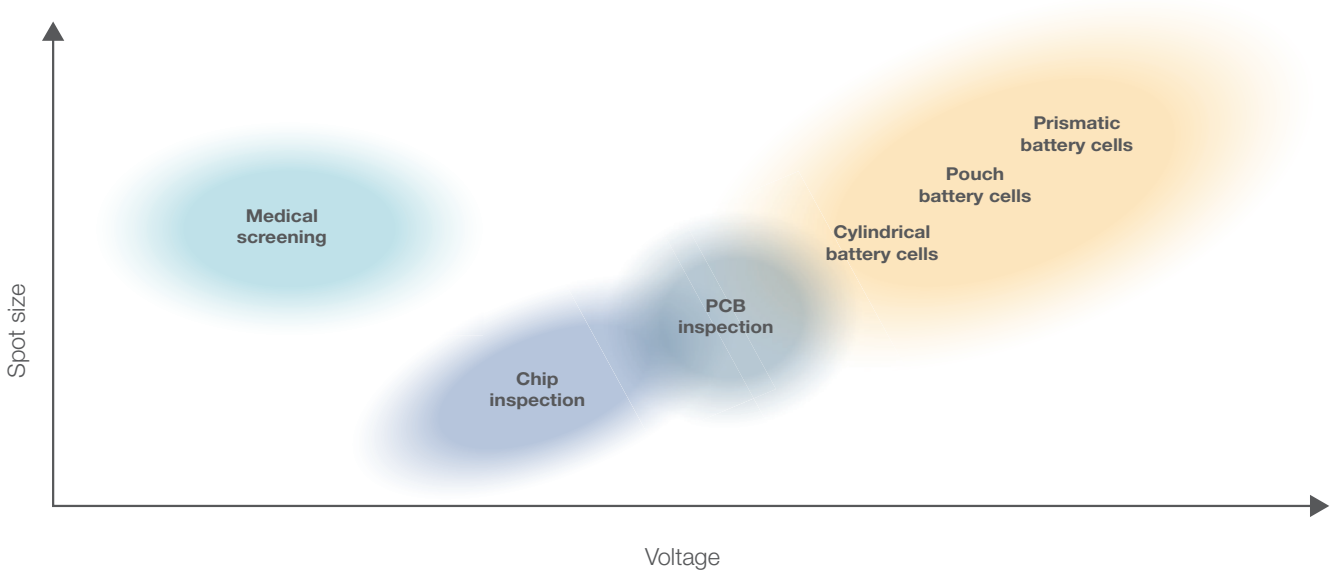



**Figure 3. Applications by voltage**

See what different members of the family have to offer and how together they answer to a broad range of applications and specification needs.

## PXS5 Microfocus X-Ray Sources

Thermo Scientific™ PXS5 Microfocus X-Ray Sources offer the shortest FOD and smallest minimum x-ray focal spot available with a maximum voltage operation of 90 KV and maximum power of 8 Watts. These products are constructed in a compact fully integrated package offered in both analog and digital interface options. The digital interface has a robust set of diagnostics and automated conditioning of the source proportional to the length of time since x-rays were last produced to maintain optimum high voltage performance. We also offer both side window and end window configurations. The sources perform with the highest resolution at limited energy and power which make them a go-to for economical solutions in manual and automated NDT (Non-destructive testing). We also manufacture versions suitable for gantry and C-arm.

Example applications include imaging of printed circuit boards, semi-conductor devices, discrete components, chip counters, lab animal fluoroscopy, dental prosthetics quality control. With three x-ray tubes for the PXS5 source available to configure between two power supply options, there is complete flexibility to optimize the right x-ray source for end user application.

## PXS10 Microfocus X-Ray Sources

Thermo Scientific™ PXS10 Microfocus X-Ray Sources are our flagship integrated x-ray source solution that operates at a maximum energy of 130 kV and up to 65 Watts. PXS10 x-ray source models vary principally with respect to beam angle and field of view, up to an ultra-wide beam angle option of 115° that delivers a truly expanded field of view. All PXS10 x-ray sources have a digital interface and a rugged design for trouble-free, long-term operation in exacting environments. There is also an optional flange extension to extend the window away from the cabinet, offering flexibility for those facing configuration constraints. Our source is ideal for industrial inspection, including AXI (automated x-ray inspection) and in-line inspection systems (24x7 operation). Notably suited for lithium batteries manufacture, the PXS10 x-ray source enables the end user to measure and inspect even dense EV (electric vehicle) battery cells. These vital but increasingly complex, multi-layered, multi-component systems typically give rise to attenuation levels that demand the highest voltage sources. Complex electronic assemblies can be equally challenging, as chip population densities are ramped up to deliver functionality in ever smaller devices attenuation levels rise.


## PXS15 Microfocus X-Ray Sources

Thermo Scientific™ PXS15 Microfocus X-Ray Sources are a robust mid-range voltage solution – 110kV – widely used for imaging and inspection tasks in the production environment. Combining aspects of performance of both the PXS5 and PXS10 sources, the PXS15 x-ray sources often represent a cost-effective solution for battery inspection, for EVs cells and the smaller, simpler lithium cells used to power smart devices. The PXS15-WB x-ray source offers the widest cone of illumination available with exceptional FOD and up to 25 Watts. As with the PXS10 x-ray source the interface is digital, and a narrow beam variant is available for those requiring a narrower field of view. Both models have a rugged design well-suited to routine industrial use.


## PXS11 Microfocus X-Ray Source

The Thermo Scientific™ PSX11 Microfocus X-Ray Source is our most affordable solution for applications that require moderate resolution from a filamentary X-ray tube that operates up to 75 KV and 7.5 Watts. This source provides a “round” focal spot performance near 45 um through a broad range of operation. This source has been used extensively for Mini C-arm fluoroscopy applications. The source is RoHs compliant, durable, compact, analog interface, and air cooled. Look to this product for cost, ease of installation and operation, and long-term reliability for intermittent use applications.

# Match your requirements: Identify a source that's optimal for you

Our portfolio of x-ray sources covers a wide range of specifications to help you identify the best source for your application

| Product family | Model | Tube | Max power | Max voltage | Max current | Min spot size | FOD | X-ray beam angle |
|---|---|---|---|---|---|---|---|---|
| PXS5 | PXS5-822 | 822 | 8 W | 80 kV | 0.178 mA | 15 µm | 12.5 +/- 0.5 mm | 34° |
| | PXS5-925 | 925 | 8 W | 90 kV | 0.180 mA | 5 µm | 12.0 ± 0.5 mm | 40° |
| | PXS5-925-LV | 925 | 8 W | 70 kV | 0.180 mA | 5 µm | 12.0 ± 0.5 mm | 40° |
| | PXS5-928-AN | 928 | 8 W | 90 kV | 0.160 mA | 4.5 µm | 6.0 mm | 108° |
| | PXS5-928 | 928 | 8 W | 90 kV | 0.160 mA | 4.5 µm | 6.0 mm | 108° |
| | PXS5-928-LV03 | 928 | 3 W | 60 kV | 0.075 mA | <5 µm | 6.0 mm | 108° |
| PXS10 | PXS10-16W | 131 | 16 W | 130 kV | 0.320 mA | 6 µm | 14.0 ± 0.5 mm | 53° |
| | PXS10-40W | 131 | 40 W | 130 kV | 0.500 mA | 6 µm | 14.0 ± 0.5 mm | 53° |
| | PXS10-65W | 131 | 65 W | 130 kV | 0.500 mA | 6 µm | 14.0 ± 0.5 mm | 53° |
| | PXS10-WB-16W | 134 | 16 W | 130 kV | 0.320 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| | PXS10-WB-40W | 134 | 40 W | 130 kV | 0.500 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| | PXS10-WB-65W | 134 | 65 W | 130 kV | 0.500 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| | PXS10-WBE-16W | 134 | 16 W | 130 kV | 0.320 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| | PXS10-WBE-40W | 134 | 40 W | 130 kV | 0.500 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| | PXS10-WBE-65W | 134 | 65 W | 130 kV | 0.500 mA | 7 µm | 10.0 ± 0.5 mm | 115° |
| PXS11 | PXS11-100-35-Rohs | 7010 | 7.5 W | 75 kV | 0.100 mA | 45 µm | 8.9 mm | 34° nominal |
| PXS15 | PXS15-NB | 110kV-NB | 25 W | 110 kV | 0.250 mA | 5 µm | 7.5 ± 1.0 mm | 90° |
| | PXS15-WB | 110kV-WB | 25 W | 110 kV | 0.250 mA | 7 µm | 7.5 ± 1.0 mm | 125° |

* All PXS10 models available in standard or lightweight (LW) shielding options

## Working with us

We are an established, global company with a network of experts, authorised distributors and robust supply chains that span the world. We have an in-depth understanding of x-ray technology, and we know how to engineer x-ray sources for the long-term. Our experts will help you to identify the best source for your application while our after-sales, spares and repair service will keep you running to plan and minimize downtime. We understand the importance of reliability and responsiveness and target exemplary levels of both.

High-performance sources. Expert support. Reliable supply. Responsive repair.

These are the hallmarks of our x-ray source offering and they make us a strong partner for any industrial or medical imaging project.

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