Application note

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## Frequently asked questions concerning cold cathode X-ray tubes/sources

### What is the advantage of a cold cathode X-ray source?

To begin with, the Oxford Instruments Cold Cathode X-ray tube uses an emerging nanotechnology material, known as Carbon Nanotubes (CNT), as the electron emission source. These nanotubes are "grown" on the cathode substrate and posses the unique ability to liberate electrons at room temperature. Thus, unlike heated electron sources, such as filaments, these CNT based cathodes are "cold" in comparison. Oxford Instruments has been working with these electron emission sources since 1997 and we introduced the first commercially available x-ray source using CNTs in November 2000. Since this time a better understanding of the benefits and detriments of this technology are emerging:

1. Cold cathodes switch on faster than heated filament (thermionic): As no heating is required, the CNT based cathodes begin to emit electrons the instant a extraction field is placed between the CNT cathode and the target anode. Thus, for applications, which require instant "on", the CNT based x-ray sources would seem more appropriate.
2. Cold cathodes consume less power: While not significant, the cold cathode does not require a power supply to heat the cathode, and thus consumes less power than the equivalent thermionic x-ray source. However, the extraction field has an efficiency of around 50%, thus reducing the benefit of this characteristic, such that there is very little difference in the total power consumption of a cold cathode x-ray source over a thermionic equivalent. That said, for portable applications, which operate on battery power, every watt is important, and therefore the cold cathode source would seem more appropriate.
3. Cold cathodes have the promise of greater robustness: When heated, thermionic filaments weaken. By example strongly tapping an incandescent light bulb when it is on will frequently break the thermionic filament. A CNT cathode does not lose any mechanical strength when operating and thus would suggest a greater degree of robustness. However, the adhesion process of ensuring the CNTs are well adhered to the underlying cathode substrate remains an issue of concern and until this issue is better understood the greater robustness remains a promise rather than a present reality.

### What is the advantage of a thermionic cathode X-ray source?

As Oxford Instruments has been manufacturing x-ray tubes with thermionic cathodes for over twenty years, we have a great deal of knowledge on their behavior. As such, there are several advantages to this technology:

1. Known technology: We fully understand how these emission cathodes function and what factors contribute to their longevity. By carefully designing the x-ray tube and power supply to match and protect the filament, we can ensure a long-lived x-ray source.
2. Lower cost: As we make thousands of these x-ray tubes the cost of manufacture is lower and we can pass along these savings in the price of the source.
3. Higher stability: Due to the nature of the electron emission the x-ray producing "focal spot" is tightly cantered on the transmission anode and does not change in characteristics as the source is used. Therefore, if the detector employed does not view the entire cone angle of the x-ray beam, the x-ray flux will remain highly stable. This can be quite appropriate for those applications where partial sampling of the x-ray beam is important.

### Why do you offer both a cold cathode x-ray source and a conventional thermionic x-ray source?

As we learn more about CNT based x-ray sources we are beginning to see that CNT sources have their applications where they are well suited (see above), but do not necessarily make sense as a total replacement. This is especially true as the cost of manufacture of a CNT based x-ray source is much higher than a themionic source. This is largely due to the emerging nature of the technology and the fact that thermionic emission filaments are used in very high quanties across a number of applications making them more cost effective. Therefore, it is our recommendation that you select the x-ray source which is appropriate for the intended application. Should your application require the features and benefits listed above, than a CNT based x-ray source seems the correct choice. However, if your

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application does not require these features or benefits, than a conventional thermionic x-ray source is the correct choice.