



## **Miniature X-Ray Sources and the Effects of Spot Size on System Performance**

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### **Goal**



- **To gain a better understanding and measure of miniature x-ray sources so that performance can be optimized in your application.**

Measuring spot size for spec sheets is not always useful because we all try to present the best possible result. We are looking for better ways to predict how the tube will perform in a given application and be able to work with you to optimize the design of the collimation system.



## Brief History of Miniature X-Ray Sources



- **Initial challenge was Voltage Standoff and Output**
- **Spot Sizes down to around 1mm**
- **Improved Centering and Spot Uniformity**
- **New Sources in Development with < 100 micron spots**

These miniature x-ray sources didn't exist commercially 10 years ago. Lots of innovation 8-10 years ago followed by a lot of incremental improvements in voltage standoff, spot quality and overall reliability of the sources. We now have a number of production tests that mimic the geometry of a particular application, but that requires knowing the system geometry. We are yet again entering a period where we are doing a lot of innovating and need to come up with ways to predict performance as we work with you to design new systems.



## Why Miniature Sources are Different than Traditional Tubes



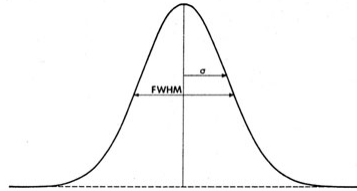
- **Space, Cost and Power Constraints**
- **Diode vs. Electron Gun Arrangement**
- **New innovations in miniature x-ray sources are making it more important to match the source with the application**

We usually do not have the space to use the same techniques used in micro-focus tubes which make our spot distribution fundamentally different. The miniature tubes essentially image the filament directly with whatever passive electron focusing we can fit in. Because of this we are also balancing emitting area against filament lifetime. The measure of a micro-focus tube, traditionally a single number for FWHM, is not as useful for the miniature tubes.

## twX The Problem with using Full Width Half Maximum (FWHM) MOXTEK

### Simple Definition of FWHM

It is given by the distance between points on the curve at which the function reaches half its maximum value.



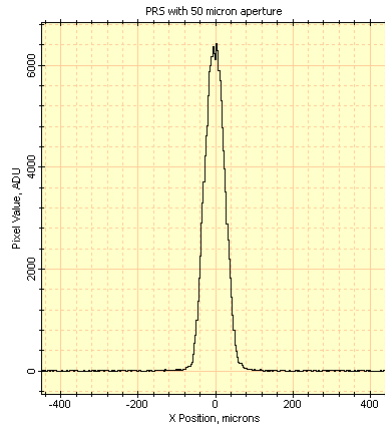
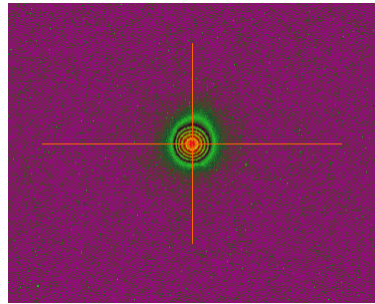
Works well for Gaussian spots.



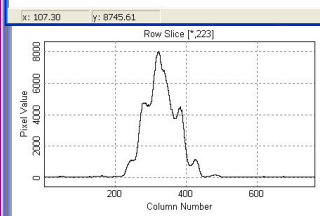
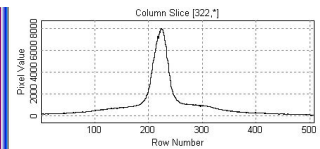
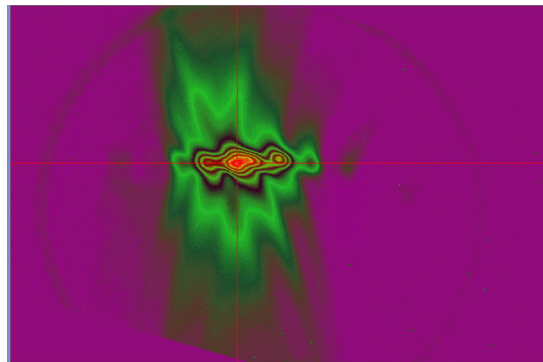
Everything is great for a Gaussian spot. You are capturing a large, known percentage of the spot based on the FWHM. FWHM is about 75%.

## twX FWHM for Non-Gaussian Examples MOXTEK

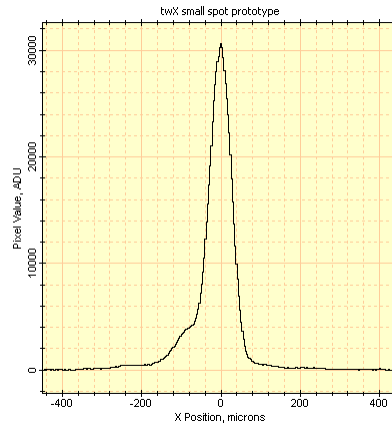
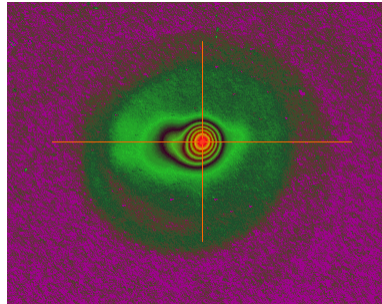
- **Artificial 50 Micron for Comparison**
- **Non Round FWHM**
  - Filament orientation can be used to optimize performance somewhat, but a single FWHM number doesn't tell the story.
- **Round Spot with "Tails" FWHM**
  - The almost background output from a wide area outside of the central spot can account for a large percentage of the total output.



This spot was created by using a 50 micron aperture to make sure that there was no emission outside.

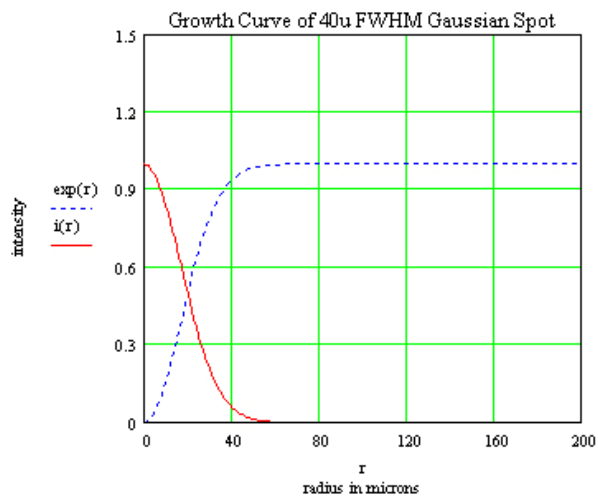
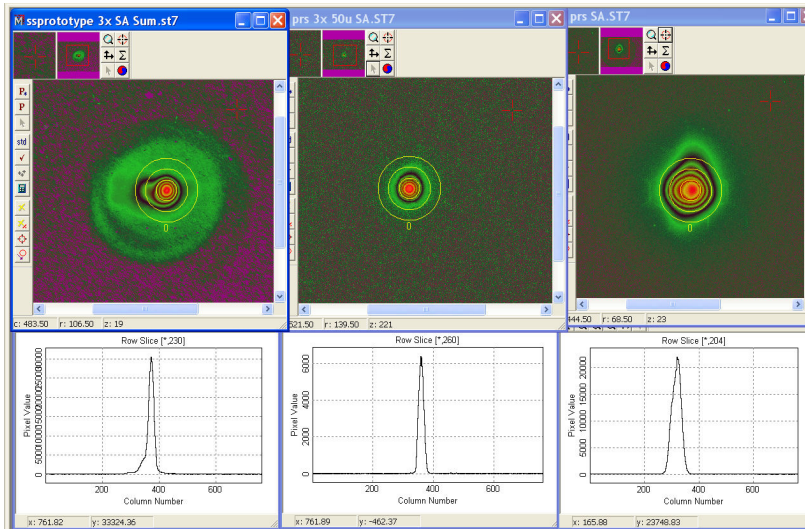


Two vastly different values for FWHM depending on the way you slice it. You can see the individual coils of the filament emitting in this example.



The spot looks nice and has a calculated FWHM close to 50 microns, but there is a substantial amount of output in the area under the curve outside of the FWHM as compared to a Gaussian spot. This will effect the output stability with even small changes in the spot position or emission characteristics of the filament.

- **Growth Curve Generation**
  - There are a number of ways to generate spot size information, each with their own strengths.
  - The growth curve shows the total percentage of the output captured as you move out radially from the center.
  - Tube Centered vs. Spot Centered Growth Curves
- **Gaussian Spot Growth Curve**



This gives a very predictable capture of output. An 80 micron diameter aperture will capture more than 95% of the output. 120 micron diameter aperture will capture more than 99%. There are two particular slopes that are of interest. Obviously a steep slope on the left indicates that more of the output is concentrated in a smaller central spot. The other slope of interest is the slope where it intersects the aperture.



## Matching Growth Curves to Specific Applications



- **Growth Curve Example #1 – Large Spot but Growth Asymptotes before Aperture**
  - Good for Long Term Stability and Lifetime
- **Growth Curve Example #2 – Small Spot with Tails**
  - Good for focusing applications

Example #1 – Not the smallest spot on the sample, but stability is positively effected by the fact that the aperture is on a very shallow portion of the growth curve.

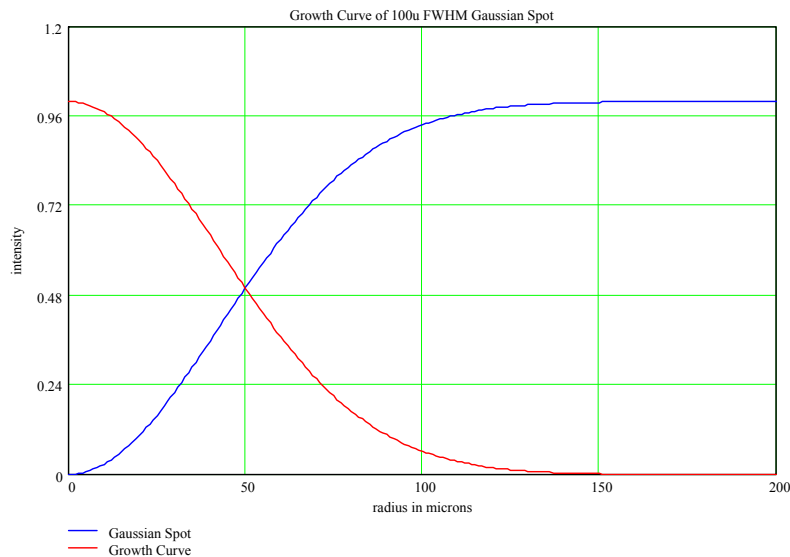
Example #2 – With proper geometry and sizing of optic acceptance, the tails will not effect the stability (only result in some wasted flux).

Obviously if we can make the tubes that have small spots and no tails, we will.

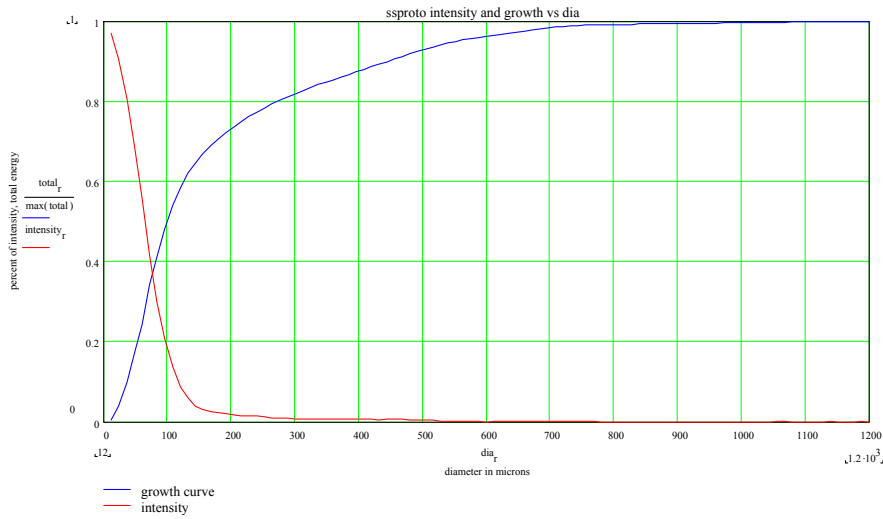
Predicting performance and designing systems will be easier, but we aren't there yet.



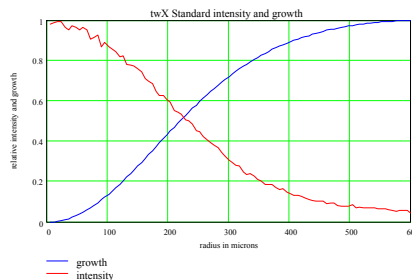
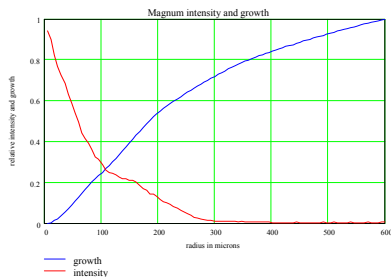
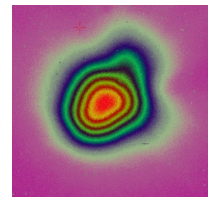
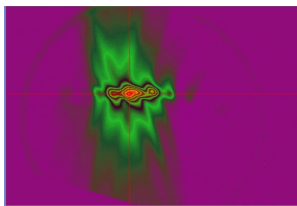
## Growth Curve #1 – Larger Spot w/ No Tails

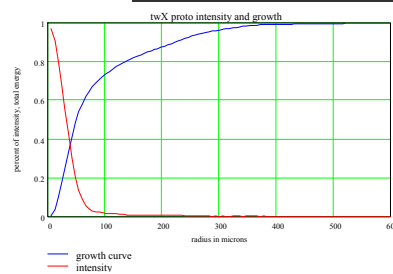
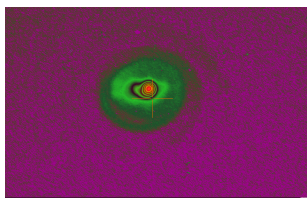
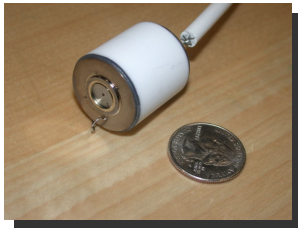


Note the slightly larger spot FWHM, but also note that the growth curve flattens out.



A smaller spot, but note that the growth curve has a significant slope outside of the central spot region.





- **White Paper on Growth Curve Creation for Miniature X-Ray Sources Coming Soon**
- **Sterling's Poster #F-23 in Exhibit Hall**
- **Moxtek Booth #41**
- **Thanks to MiraMetrics for software support and SBIG for camera support**