# Optical Resolution of Nikon Coolscan Scanners.

*G. Shtengel*

## 1 Introduction

Nikon Super Coolscan IV, 4000, V, 5000, as well as 8000 and 9000 have all been discontinued by Nikon as of 2015, but are still used widely by amateurs and professional photographers to digitize film images. All of these scanners have optical resolution specification of 4000 dots per inch (dpi). I tried to estimate the actual resolution of these scanners under different conditions.

## 2 Methods

I used Nikon Scan 4 software to acquire all images. All the data (except for that in Figure 10, where I evaluated the effect of cleaning the mirror) was collected on the freshly serviced scanners (the imaging mirrors were cleaned). I have used two approaches to estimate the scanner resolution:

1. I had scanned a 35mm film slide, "Modern Photography Projector Lens Test" (Figure 1.), provided by S. Cherpitel. This allows for relatively easy direct visual evaluation of resolution, however the results are not easily quantifiable.


*Figure 1. Image of "Modern Photography Projector Lens Test" 35mm slide, courtesy of S.Cherpital.*

All images of this slide were taken with 4000dpi, ICE off, no post-processing (GEM=0, ROC=0). I used only a center portion (inside yellow rectangle in Figure 1), comparing these, taken under optimal focal condition, for different scanners.

2. In order to establish a quantitative resolution measure, I turned to a technique used in microscopy, Fourier Shell Correlation (FSC) analysis (*1*). Typically, FSC requires two images taken on the same sample consecutively, so that the signal can be assumed to be the same, and noise is different. The Fourier cross-correlation amplitude (normalized by Fourier signal) decays with increasing frequency, few cut-off criteria had been proposed. In order to perform FSC analysis, I took two consecutive images (for every imaging condition) of a very dusty 35mm Ektachrome slide (Figure 2,

left). I then used only green channel of each image for FSC analysis, a crop of the green channel image is in Figure 2, right, the dust is clearly visible.

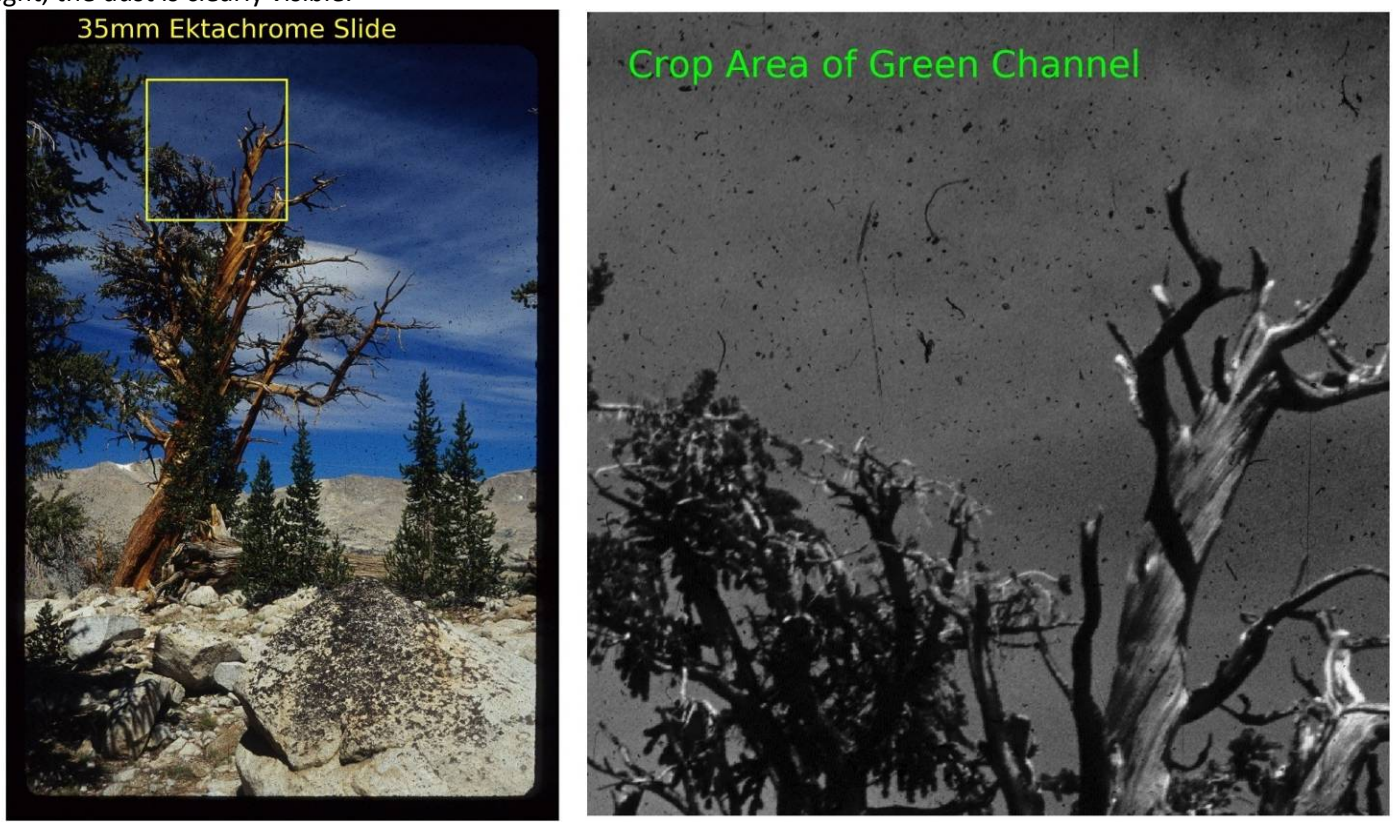


*Figure 2. The scan of 35mm Ektachrome slide (left), a crop of the green channel image (right). The image was taken with LS-5000 SN416255, using Nikon Scan 4 with 4000dpi setting, ICE off, no post processing (GEM=0).*

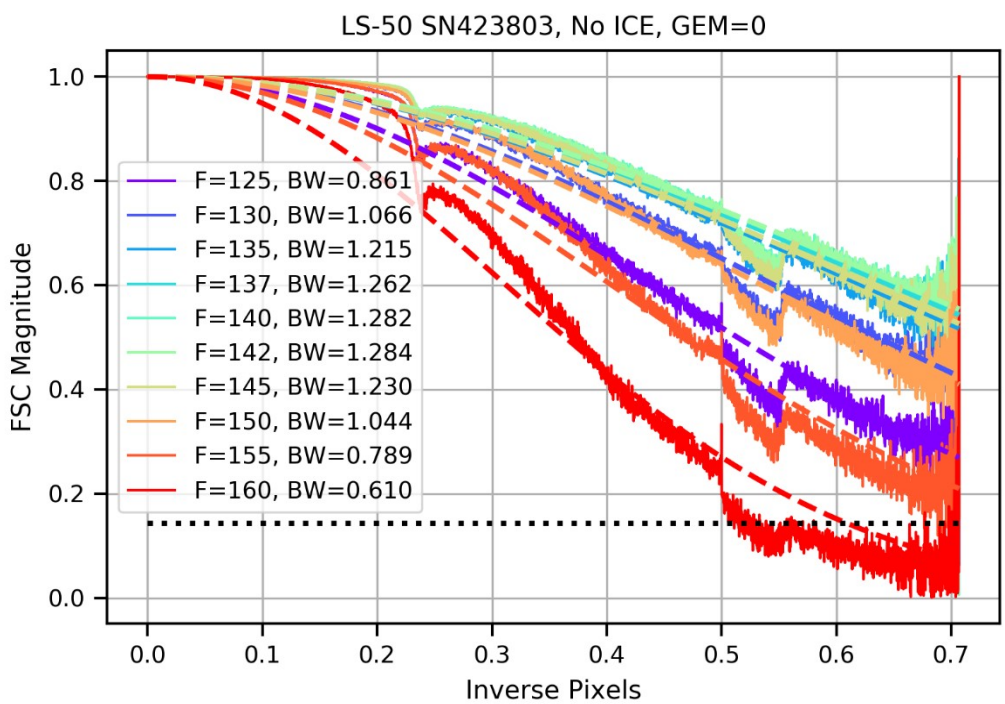


*Figure 3. FSC curves for scans acquired using Nikon V (LS-50) and Nikon Scan 4 software for different focus settings. Solid lines are actual FSC curves, dashed lines of the same color are Gaussian fits. An intersection of a Gaussian fit with FSC=0.143 is reported as bandwidth (BW).*

A typical result of this procedure is shown in Figure 3. FSC curves for scans were acquired using Nikon V (LS-50) and Nikon Scan 4 software for different focus settings. Solid lines are actual FSC curves, dashed lines of the same color are Gaussian fits. As one can see the Gaussian fit is far from ideal, but I had to use some fit for the curves that do not cross

the noise cut-off value of FSC=0.143. An intersection of a gaussian fit with FSC=0.143 is reported as bandwidth (BW). The value BW and its dependence on scanning conditions and software settings can then be analyzed for different scanners.

# 3 Results

## 3.1 Comparison of the scanner resolution using Modern Photography Projector Lens Test

The center portions of the scans of Modern Photography Projector Lens Test acquired with different scanners with best focus setting (Nikon Scan) are shown in Figure 4 (my data) and Figure 5 (taken by S.Cherpitel). 35mm scanners consistently outperform medium format scanners.

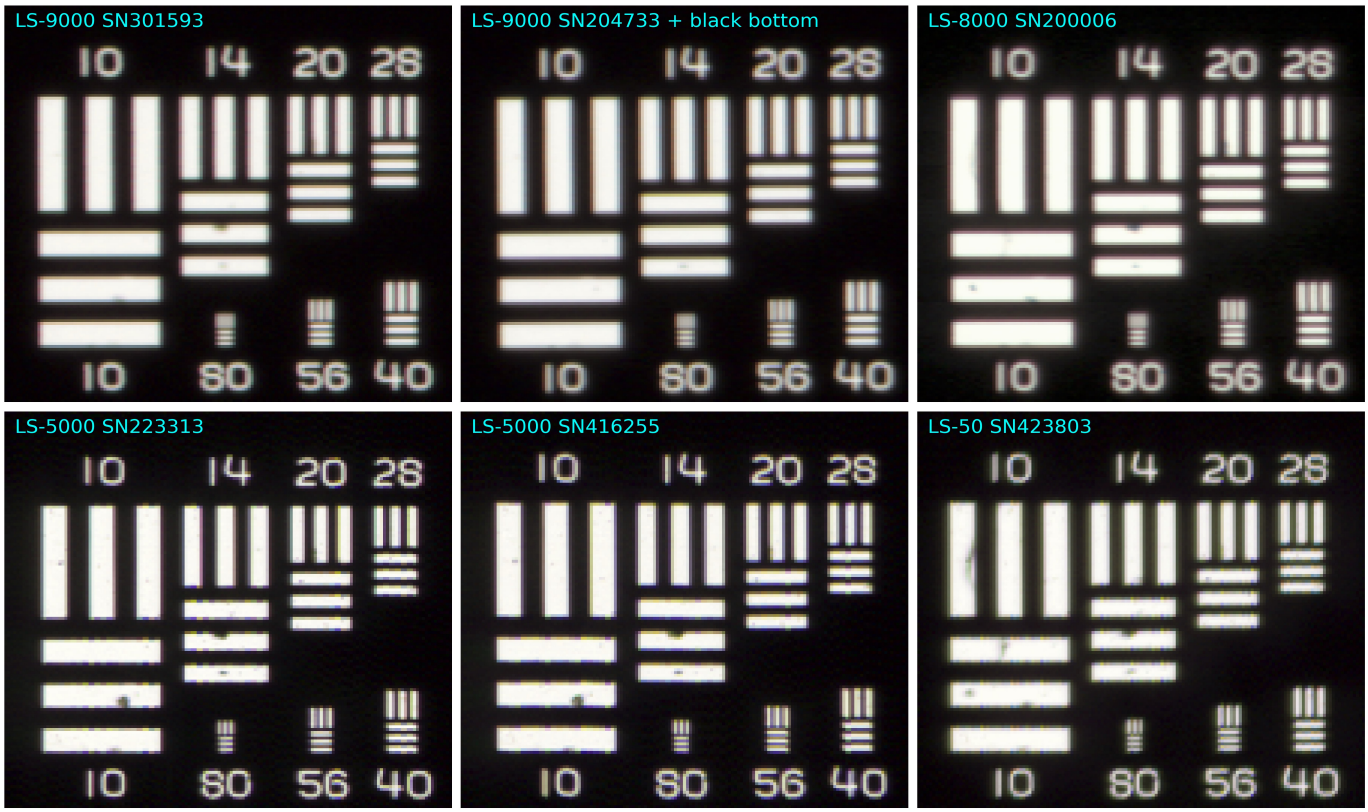


*Figure 4. Scans of Modern Photography Projector Lens Test performed using best focus setting (Nikon Scan) acquired on different medium format (top row) and 35mm (bottom row) scanners.*

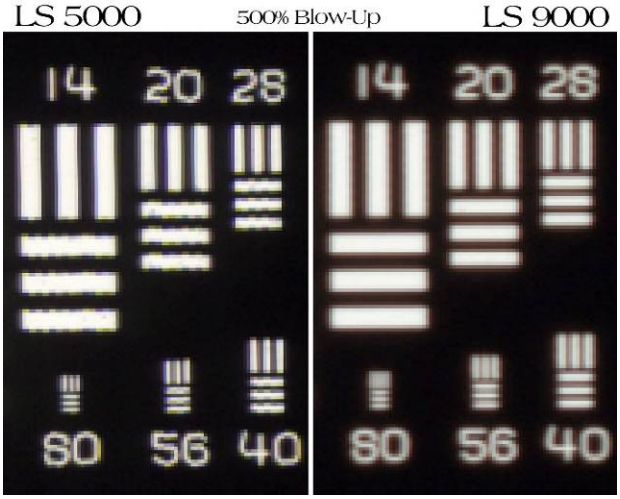


*Figure 5. Scans of Modern Photography Projector Lens Test performed by S. Cherpitel on his scanners.*

## 3.2 Comparison of the scanner resolution using dusty 35mm Ektachrome slide.

Before applying FSC analysis, I visually compared the scans of 35mm Ektachrome slide taken with LS-5000 and LS-9000 scanners, the typical results are shown in Figure 6. Again, 35mm scanners consistently outperform medium format scanners.

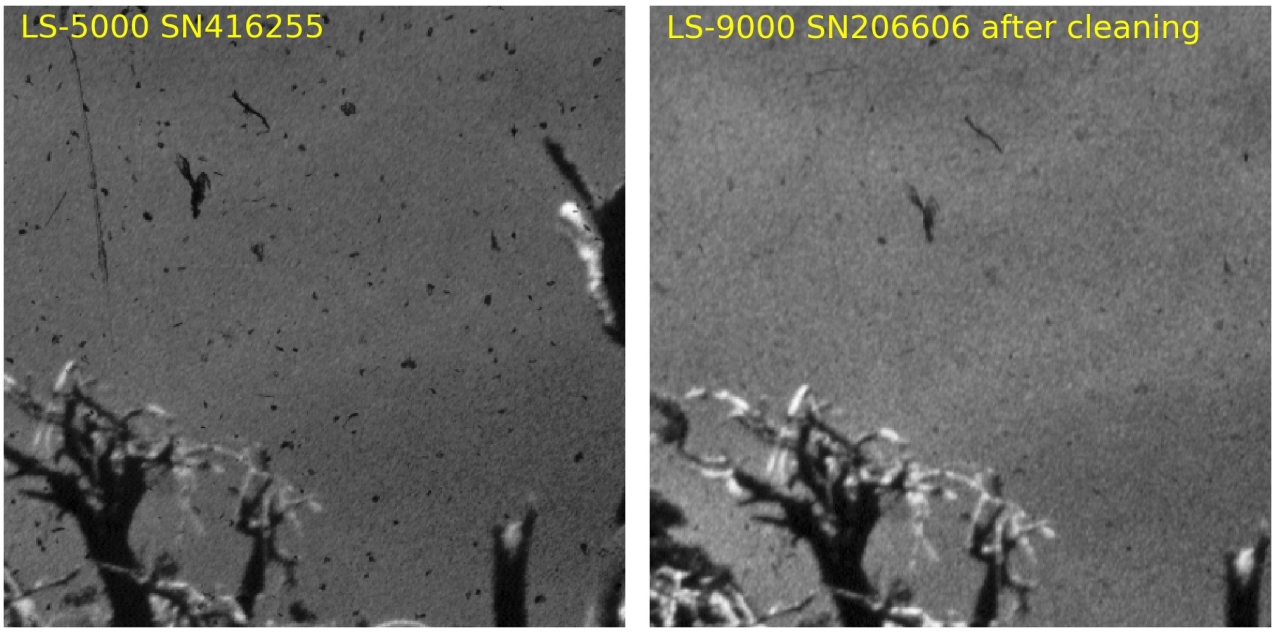


*Figure 6. Crops of the center area (300x300 pixels) of the scans of 35mm Ektachrome slide acquired with LS-5000 SN416255 (left) and LS-9000 SN206606 (right), using Nikon Scan 4 with 4000dpi setting, ICE off, no post processing (GEM=0).*

## 3.3 Comparison of the scanner resolution using FSC Analysis of scans of the dusty 35mm Ektachrome slide.

I had then determined resolution BW of different scanners using FSC analysis performed on of 35mm Ektachrome slide. For each scanner I determined BW over a range of focus settings around optimal value, the results are shown in Figure 7. Again 35-mm scanners consistently outperform the medium format scanners.

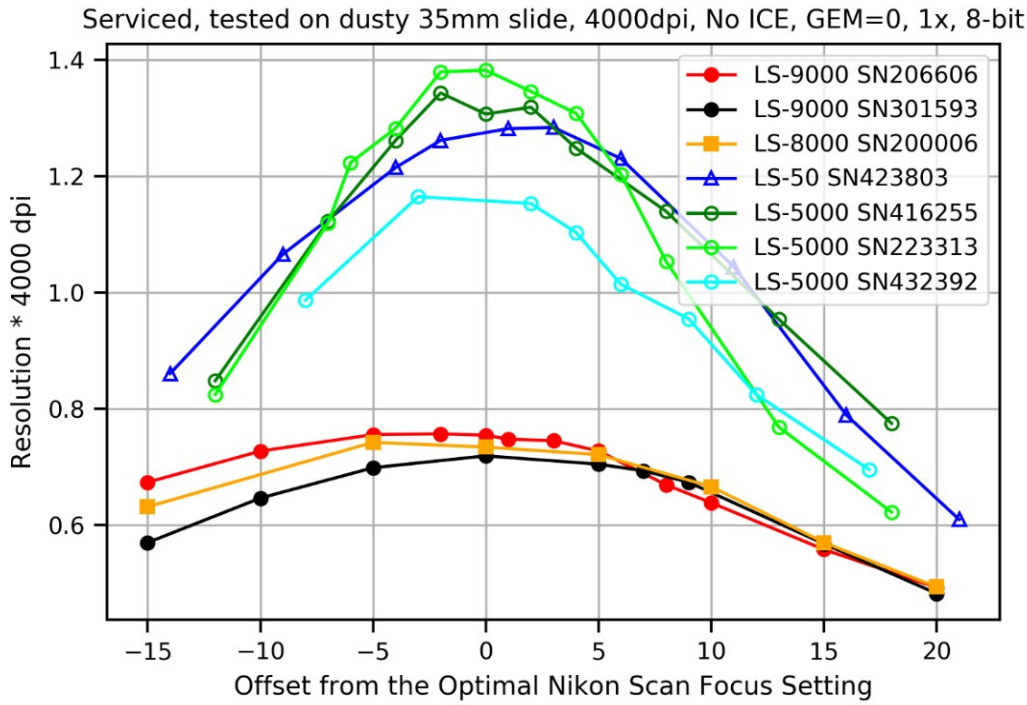


*Figure 7. Resolution BW of different scanners determined using FSC analysis.*

## 3.4 Scanner resolution: effect of cleaning the imaging mirror

I had investigated how much dirty mirror can degrade the scanner resolution. I used a Nikon LS-9000 scanner SN206606 that I had for service. I tested that scanner's resolution before and after cleaning the mirror. The photographs of the mirror before and after cleaning are in the Figure 8 . As you can see the mirror before cleaning was

dusty and cloudy. But it should be mentioned that it was not dirty enough to cause hardware failure during start-up testing, or manifest itself in any way other than very slight degradation of sharpness.

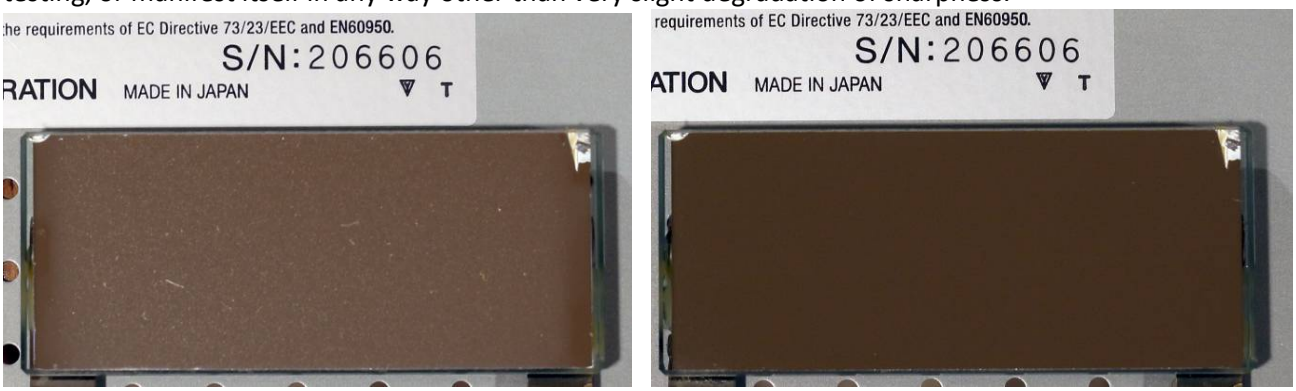


*Figure 8. Photographs of the imaging mirror of the Nikon LS-9000 scanner SN 206606 before (left) and after (right) cleaning.*

The crops of the center area (300x300 pixels) of the scans of 35mm Ektachrome slide acquired with LS-9000 SN206606 before (left) and after (right) cleaning the mirror are shown in Figure 9, and upon close inspection one can see that very thin features are better resolved in the right (after cleaning) scan.

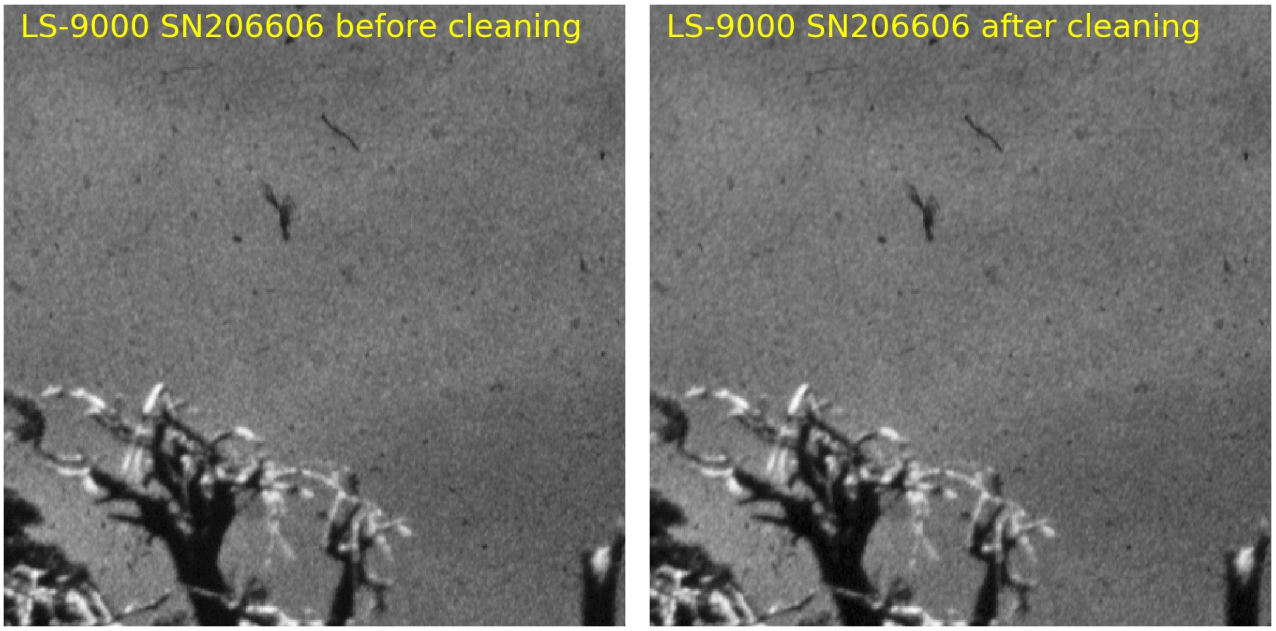


*Figure 9. Crops of the center area (300x300 pixels) of the scans of 35mm Ektachrome slide acquired with LS-9000 SN206606 before (left) and after (right) cleaning the mirror. Scan were acquired using Nikon Scan 4 with 4000dpi setting, ICE off, no post processing (GEM=0).*

The results of FSC analysis of the scans acquired before and after the mirror cleaning are shown in Figure 10. Here the difference is a little bit easier to see.

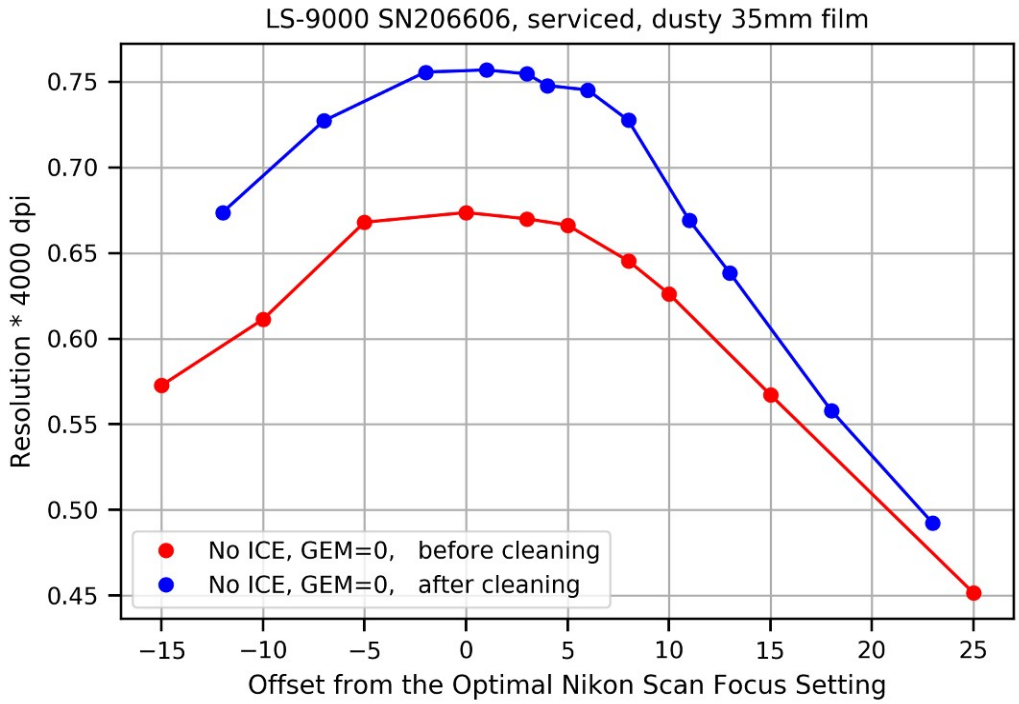


*Figure 10. Resolution BW of a scanner (determined using FSC analysis) before (red) and after (blue) cleaning the mirror.*

## 3.5 Scanner resolution: effect of post-processing

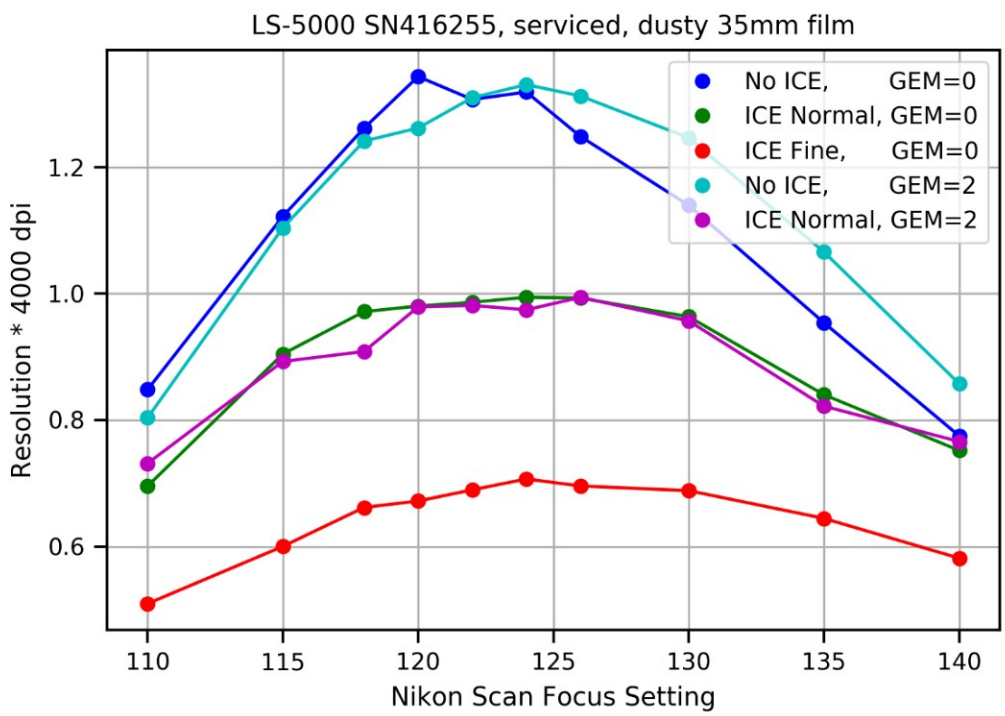


*Figure 11. Resolution BW of a scanner (determined using FSC analysis) with different degrees of post-processing.*

# 4 Conclusions

- Dedicated 35mm (LS-50 and LS-5000 (and I suspect LS-4000) have almost twice the resolution of medium format (LS-8000 and LS-9000) scanners.

- I suspect the reason is compromises in lens design required for wide field of view lens needed for MF scanners.

# 5 References

1. M. van Heel, M. Schatz, Fourier shell correlation threshold criteria. *J. Struct. Biol.* **151**, 250–262 (2005).