

# *HREM-Filters Pro/Lite*

## *User's Guide*

*DigitalMicrograph Plugin*  
*for*  
*Image Filter Functions*

*Pro: Commercial Software*  
*Lite: Free Software*

**HREM Research Inc.**  
14-48 Matsukazedai  
Higashimatsuyama, Saitama 355-0055

**Version 1.5**  
2009/02/01

---

# 1. Introduction

---

HREM-Filters Pro/Lite is a plug-in for use in Gatan's DigitalMicrograph for Windows v.3.8 or later. However, we will recommend you to use the latest version.

This HREM-Filters Pro/Lite User's Guide is written to provide information on the basic functions of the HREM-Filters Pro/Lite software, a procedure for installation of the Plug-In, some general tips on operation. This Guide assumes the user is familiar with image manipulation using DigitalMicrograph as well as Windows operating system.

**Note:** HREM-Filters Lite is free software, so anyone can use this software without a license. However, HREM Research Inc. does not renounce a copyright of this software.

## Technical Support

General enquiries on the HREM-Filters should be sent to:

HREM Research Inc.

Email: [support@hremresearch.com](mailto:support@hremresearch.com)

Web: [www.hremresearch.com](http://www.hremresearch.com)

Fax: (81) 493-35-3919

## Copyright Statements

© Copyright 2006-2009 HREM Research Inc.

All rights reserved. This manual is protected by international copyright laws and treaties. Unauthorized reproduction and distribution of this manual, or any portion of it, will be prosecuted to the maximum extent possible and may result in severe civil and criminal penalties.

DigitalMicrograph is a trade mark of Gatan Inc.

---

## 2. Installation

---

This chapter describes hardware and software requirements to run the HREM-Filters Pro/Lite plug-in and an installation procedure of the plug-in.

---

### 2.1 Requirements

---

The HREM-Filters Pro/Lite plug-in runs under DigitalMicrograph environment, and the software and hardware requirements are similar to those for DigitalMicrograph itself.

#### 2.1.1 Hardware requirement

The HREM-Filters Pro is commercial software and thus requires a license key (a USB dongle), while the HREM-Filters Lite is free software and thus requires no license key.

#### 2.1.2 Software requirement

The following is a list of the software requirements necessary to run the HREM-Filters Pro/Lite plug-in:

- **DigitalMicrograph for Windows (version 3.8 or later).**
- **USB Key Driver (only required for HREM-Filters Pro)**

---

## 2.2 Software Installation

---

The following modules should be installed. Please consult the ReadMe file for installation. The following modules should be placed in the folder “PlugIns” on the same level of the DigitalMicrograph.

- **HREM-Filters Pro or HREM-Filters Lite Plug-in (.gtk and .dll)**
- **HREM Mouse Tool Plug-in (Free-ware available at [www.hremresearch.com](http://www.hremresearch.com))**
- **IPU Plug-in (only required for HREM-Filters Pro; Free-ware available at [www.hremresearch.com](http://www.hremresearch.com))**
- **USB Key Driver (only required for HREM-Filters Pro)**

**Note:** The PlugIns folder should exist under a normal installation of the DigitalMicrograph.

### **Installing HREM-Filters Pro or HREM-Filters Lite Plug-in**

HREM-Filters Pro or HREM-Filters Lite (.gtk and .dll) can be installed by drag-and-drop copy to the folder “PlugIns” on the same level of the DigitalMicrograph.

### **Installing HREM Mouse Tool Plug-in**

This is a free plug-in. Please download the plug-in from the Scripts/Plugins page and install it according to the ReadMe file.

### **Installing IPU Plug-in**

This is a free plug-in. Please download the plug-in from the Scripts/Plugins page and install it according to the ReadMe file. This plug-in is required by HREM-Filters Pro in order to extend Fourier transform capability. However, anyone can use the IPU Plug-in to calculate Fourier transform of an arbitrary sized image.

When the DigitalMicrograph is launched after placing the plug-ins the PlugIns folder, HREM-Filters Pro/Lite menu (Filters) commands will be appeared under “Filters” menu and the Mouse tool will be appeared as an addition to the standard tools.

### **Installing Key Driver**

The user key driver should be installed by following the instructions given by the key driver installer (**only required for HREM-Filters Pro**). The key driver installer comes with HREM Filters Pro, or you can find it on our web site.

---

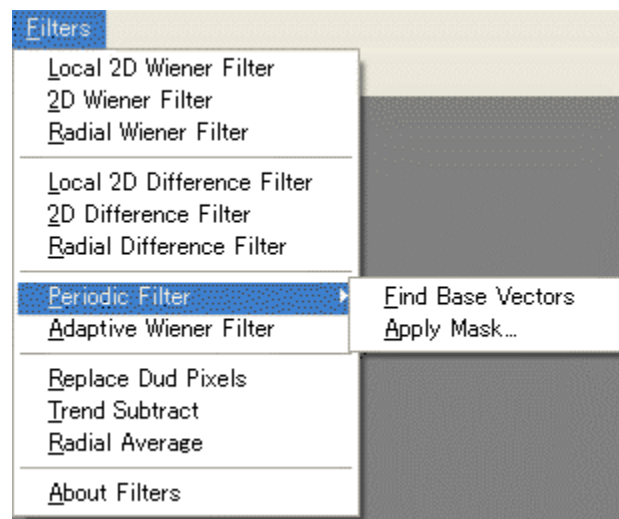
## 3. Getting Started...

---

Using the HREM-Filters Pro/Lite is very simple. All the operations are menu driven, and process the front *active* image. This chapter briefly explains each command.

### 3.1 HREM-Filters

---



Filters Pro/Lite Menu.

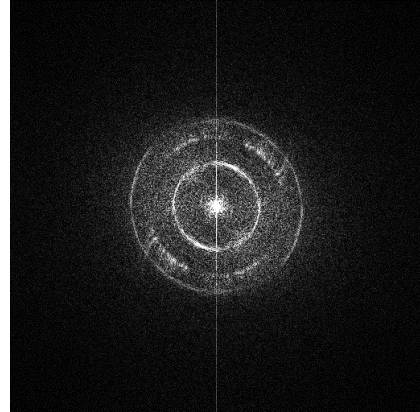
Local 2D Wiener, 2D Wiener, Local 2D Difference and 2D Difference Filters and Apply Mask... are available only for Filters *Pro*. The same commands that are available for *Lite* may be so optimized as *Pro*, and take more time than *Pro* version.

---

We will use the following image of crysotile, a clay minerals, taken by Prof. Kogure, Univ. of Tokyo. This is not an ideal crystal showing a simple translational symmetry, and thus clearly shows a power of Filters Pro.



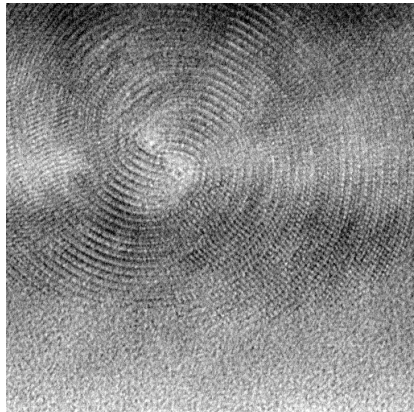
Original Image (crysotile)



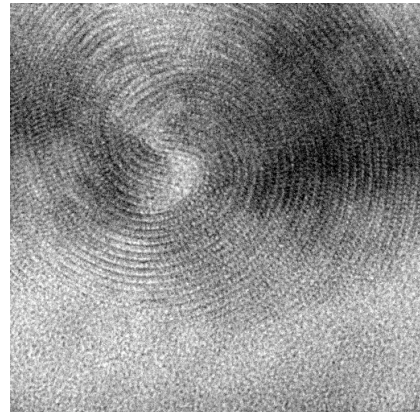
Fourier transform

### 3.1.1 Radial Wiener/Difference Filter

A background in Filter is estimated by radial average of Fourier transform of the whole area.



Radial Wiener filtered image

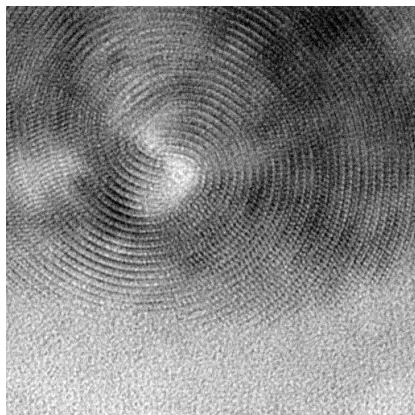


Residual of the original image

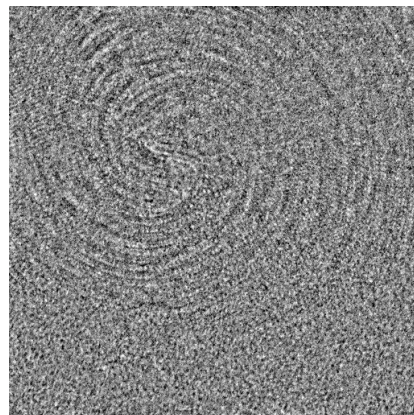
---

### 3.1.2 2D Wiener/Difference Filter (Pro Only)

A smoothed two-dimensional trend of Fourier transform of the whole area is used as a background in Filter.



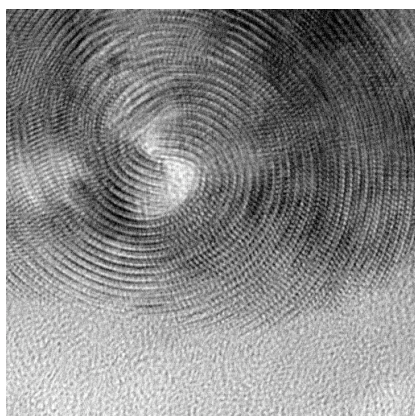
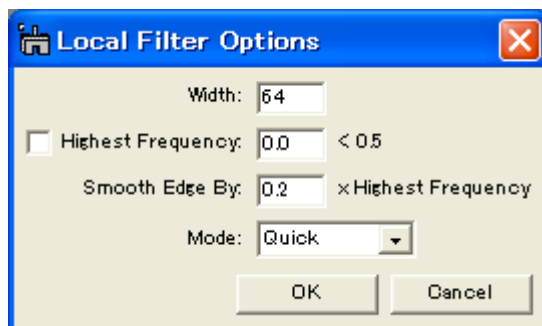
2D Wiener filtered image



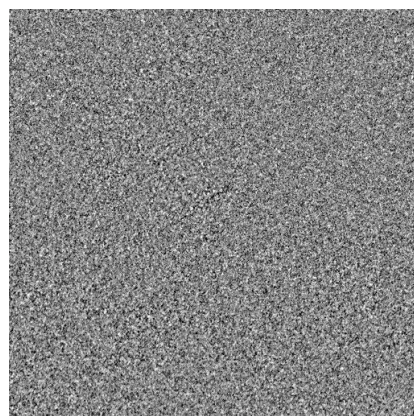
Residual of the original image

### 3.1.3 Local 2D Wiener/Difference Filter (Pro Only)

A background in Filter is locally estimated by smoothed two-dimensional trends of Fourier transform of finite areas. The size of the area is controlled by the **Size** parameter below.



Local 2D Wiener filtered image



Residual of the original image



---

## 3.2 Other Filters

---

### 3.2.1 Periodic Filter

DigitalMicrograph has a set of mask tools for Fourier filtering. However, it is not easy to set up a set of base vectors using a Periodic Mask tool for a Periodic Filter. The commands under this menu will work the Periodic Mask tool of DigitalMicrograph.



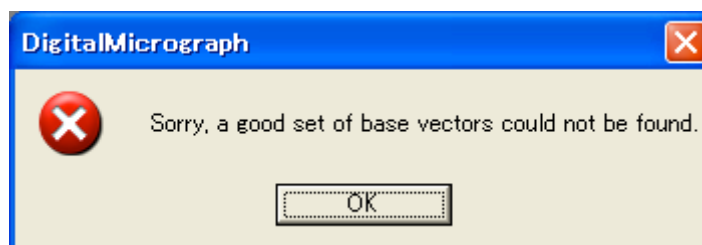
How to use “Periodic Filter”:

1. Specify any lattice points on the base vector directions by using the Periodic Mask tool.
2. Choose “Find Base Vectors” command when the masked image is at the front.
3. Adjust a mask size using the Periodic Mask tool.
4. Apply a mask using “Apply Mask...” command under the Process menu or Periodic Filter menu.

#### 3.2.1.1 Find Base Vectors (Using Periodic Mask tool)

This command will find a precise base vectors for a Periodic Filter.

1. Select any lattice points on two base vector directions by using the Periodic Mask tool.
2. (Optional) Put a Point ROI on one spot, when you want to use the spots on the lines passing through the Point ROI to find the base vectors.
3. Choose this command when the masked image is at the front, then true base vectors along the specified direction will be estimated precisely based on a least-square technique. Please note that user has to specify a set of correct directions to cover all the lattice points.
4. Make sure the base vectors are correct. If the command fails to find the correct base vectors, you will get a following message:

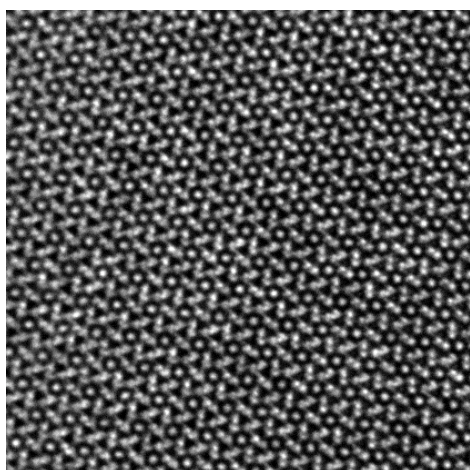


Then, you may want to try other set of lattice points using the Periodic Mask tool. Before trying another lattice points, you may also want to try with the Option (Step 2) using the same lattice points.

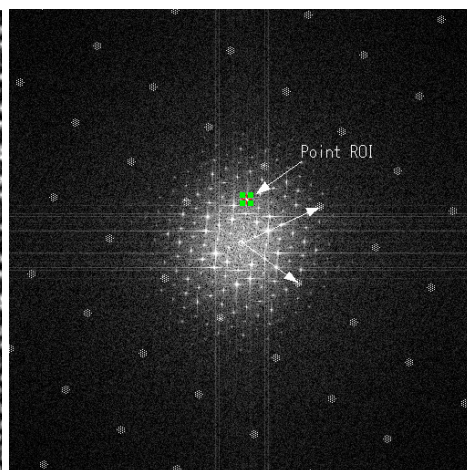
5. Adjust a mask size using the Periodic Mask tool.

When an image size is large, Filters Lite will take some time to get a result compared with Filters Pro.

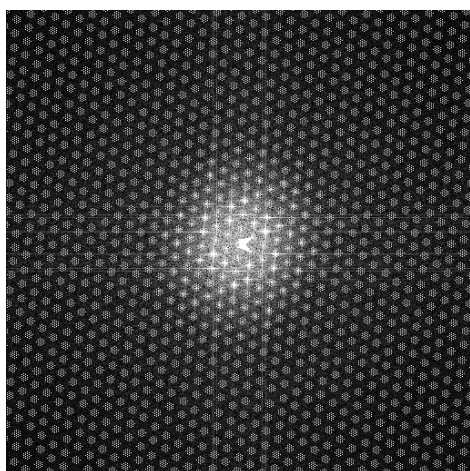




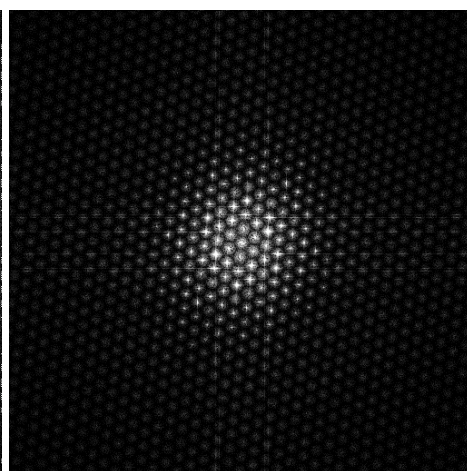
Original image (512x512) (Si<sub>3</sub>N<sub>4</sub>:  
Courtesy of C. Kisielowski)



Two lattice points on the base vector  
directions selected by using the  
Periodic Mask tool. Note an optional  
Point ROI.



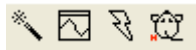
Base vectors and lattice positions  
estimated by using this command.



Mask applied by using the Apply Mask  
command of the Process menu.

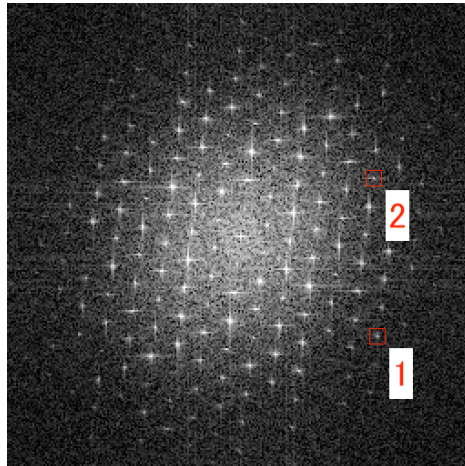
---

### 3.2.1.2 Find Base Vectors (Using Mouse tool)

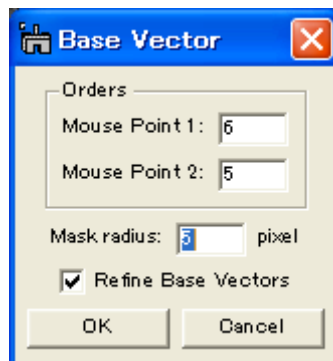


This command will find a precise base vectors for Periodic Filtering using the Mouse tool.

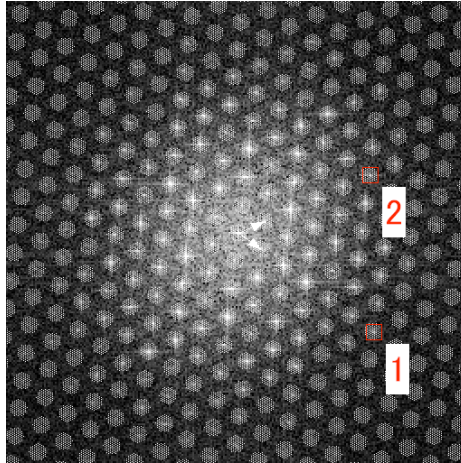
1. Select any lattice points on two base vector directions by using the Mouse tool.



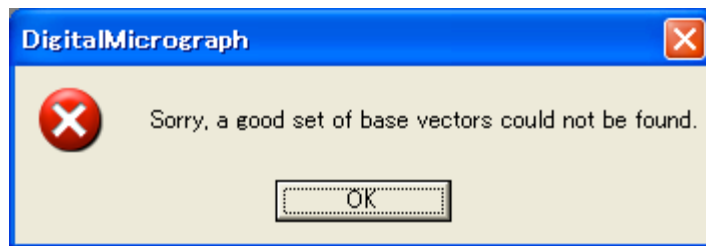
2. Choose this command when the masked image is at the front, then the following dialog will appear:



Here, you have to specify the order of the reflections specified by the Mouse tool. You can here specify the mask radius. If you check “Refine Base Vectors,” then true base vectors along the specified direction will be estimated precisely based on a least-square technique. Please note that user has to specify a set of correct directions to cover all the lattice points.



3. Make sure the base vectors are correct. If the command fails to find the correct base vectors,

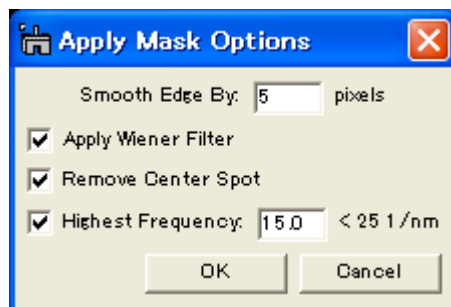


- Then, you may want to try other set of lattice points using the Mouse tool.
4. Adjust a mask size using the Periodic Mask tool.

When an image size is large, Filters Lite will take some time to get a result compared with Filters Pro.

### 3.2.1.3 Apply Mask...(Pro Only)

This is an extended version of the command “Apply Mask...” under the Process menu of DigitalMicrograph. There are several options that will reduce random noise from the final filtered image.

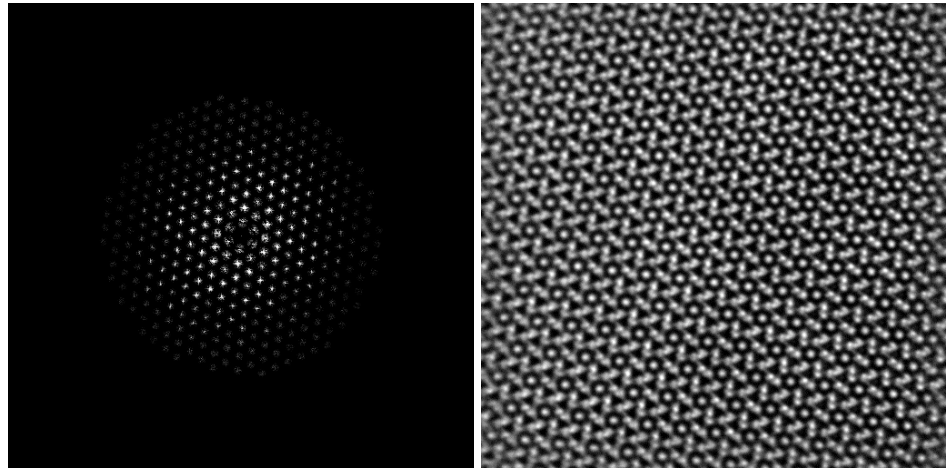


Apply Wiener Filter: Amplitude of the spot is modified by a Wiener estimate

$$F \Rightarrow \frac{|F|^2 - |F_b|^2}{|F_b|^2} F$$

where  $F_b$  is average amplitude around each spot.

- 
- Remove Center Spot: Amplitude around the center spot is set to zero except the origin single point.
- Highest Frequency: Amplitude beyond this value is set to zero.  
If the image is calibrated, the highest frequency should be given in an absolute scale, where the maximum frequency is 0.5/(sampling interval).  
If the image is not calibrated, the highest frequency should be given in a relative scale, where the maximum frequency is 0.5.



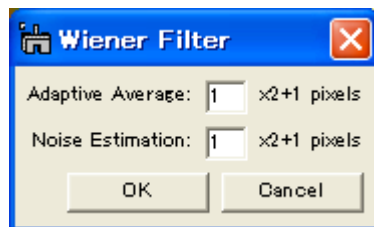
Mask applied by using the extended Apply Mask command.

Filtered image.

### 3.2.2 Adaptive Wiener Filter

This command applies a linear filter (local average) to an image *adaptively* according to the local image variance. The sizes of a local average and local variance can be controlled by “Adaptive Average” and “Noise Estimation”, respectively. If the variance is large, the filter performs less smoothing, while the variance is small, the filter performs more smoothing.

The adaptive filter is more selective than a simple local average filter, preserving edges and other high-frequency parts of an image.





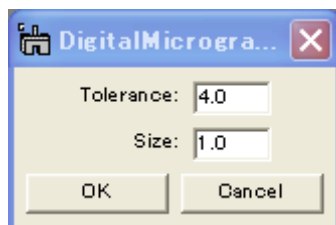
---

## 3.3 HREM-Filters Utilities

---

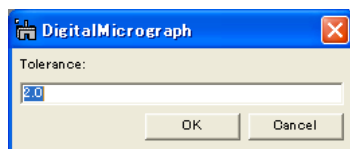
### 3.3.1 Replace Dud Pixels

This command will remove dud image points due to bad pixels of a CCD camera or due to uncontrollable x-ray or cosmic ray. The values of the dud pixels will be replaced by a local mean. This is an automatic version of **Zapper** tool of DigitalMicrograph's standard tools.



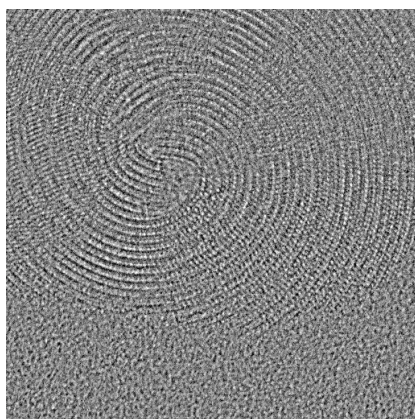
The size of a cluster of dud points can be controlled by the **Size** parameter. The **Tolerance** controls a degree of singularity in terms of a local standard deviation. This will work ideally for small isolated clusters.

For a long connected dud image pixels, an area that includes the dud pixels may be indicated by a **ROI** tool manually. Then, the dud pixels will be replaced by a local mean, when a pixel differs from the local mean by a specified **tolerance** times the variance of the area.



### 3.3.2 Trend Subtract

This command will remove a smoothed trend of an image, and makes a structural detail to be recognized more clearly. When an image size is large, Filters Lite will take some time to get a result compared with Filters Pro.



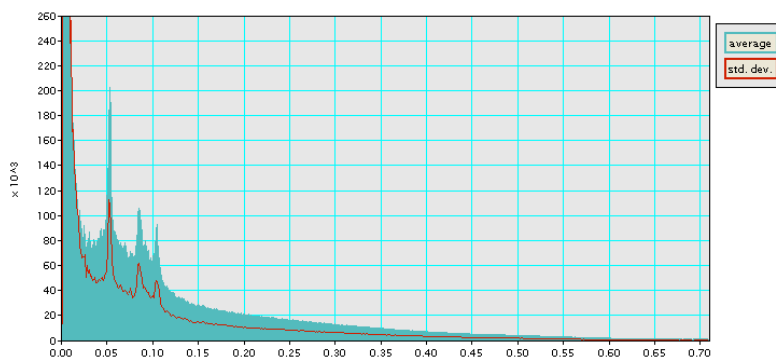
Trend Subtracted image

---

### 3.3.3 Radial Average

This command will calculate an average profile over the pixels on the same radial distance from its image center. If the image is complex number such as a Fourier transform of an image, a modulus will be averaged.

This command will also calculate a standard deviation profile, although the profile is hidden by default. You can see the standard deviation profile by choosing “Show std. dev.” on a context menu that will appear by clicking a right mouse button on the “std. dev.” legend.



Radial average profile (Standard deviation profile is set to “show.”)

---

## 4. Filter Description

---

### 4.1 Fourier Transform

---

An observed signal  $F_o$  in Fourier transform may be written as a sum of a true signal  $F_c$  due to a crystal part and a background  $F_b$  due to a non-crystal part:  $F_o = F_c + F_b$ . If we assume the true signal and the background are mutually independent, then we may be able to write  $|F_o|^2 \approx |F_c|^2 + |F_b|^2$ .

### 4.2 Wiener Filter

---

The Wiener filter seeks a solution that minimizes the summed square difference between the true signal  $F_c$  and its estimate  $\hat{F}_c$  resulting

$$\hat{F}_c = \frac{|F_c|^2}{|F_c|^2 + |F_b|^2} F_o \approx \frac{|F_o|^2 - |\hat{F}_b|^2}{|F_o|^2} F_o = \frac{|F_o|^2 - |\hat{F}_b|^2}{|F_o|} e^{i\phi_o},$$

where  $\phi_o$  is the phase of the observed signal  $F_o$  and  $\hat{F}_b$  the estimate of the background. Here, we assume  $F_c$  and  $F_b$  are independent.

If  $|F_o| - |\hat{F}_b| \leq 0$ ,  $\hat{F}_c$  is set to zero.

### 4.3 Difference Filter

---

The Difference filter (the background subtraction filter) is simply given by

$$\hat{F}_c = (|F_o| - |\hat{F}_b|) e^{i\phi_o},$$

where  $\phi_o$  is the phase of the observed signal  $F_o$  and  $\hat{F}_b$  the estimate of the background. If  $|F_o| - |\hat{F}_b| \leq 0$ ,  $\hat{F}_c$  is set to zero.

Reference: R. Kilaas, *J. Microscopy* 190 (1997) 45-51.



---

## 4.4 Background Estimation

---

In order to use either filter we have to estimate a background contribution  $\hat{F}_b$ . A radial average background has been commonly used. Here, we propose new backgrounds.

### *1. Radial Background*

Normally, the background is estimated as a radial average of the Fourier transform of the whole image assuming that the contribution from amorphous (non-periodic) materials varies slowly.

Reference: L.D. Marks, *Ultramicroscopy* 62 (1996) 43-52; R. Kilaas, *J. Microscopy* 190 (1997) 45-51.

### *2. Two-Dimensional Background*

A radial background will not work, when structure information appears at the same distance from the origin in Fourier space. Thus, we developed a novel approach based on P-spline fitting to estimate a smoothed two-dimensional background in Fourier space.

Reference: P.H.C. Eilers et al., *Computational Statistics and Data Analysis* 50 (2006) 61-76.

### *3. Local Two-Dimensional Background*

When an orientation of periodic structure is different locally, the background estimated for the whole image is not adequate. Thus, a set of two-dimensional backgrounds in Fourier space is estimated by dividing an image into local small areas.

### *4. Periodic Mask Background*

A periodic mask is frequently applied to a Fourier transform of a lattice image. We may be able to modify a simple periodic filter to a Wiener type filter, where a background is estimated for each diffraction spot from a surrounding area of each mask.