Smith-Purcell radiation and reconstruction techniques

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25 March 2015

Plan

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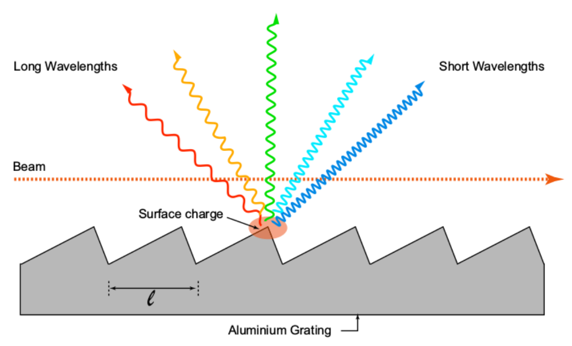
- Intro
- Simulation
- Results
- Stability of reconstruction
- DAQ for SP at Frascati

Smith-Purcell radiation



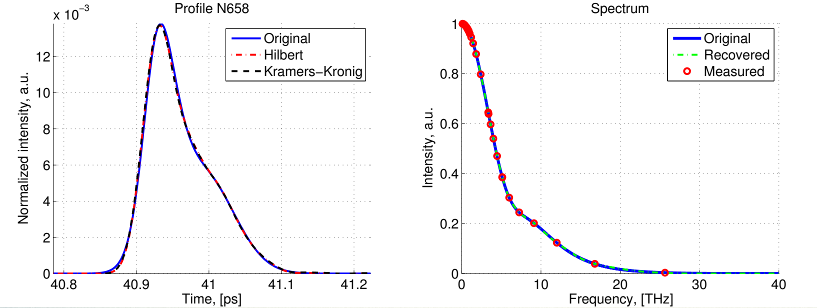
Smith-Purcell radiation is the radiation produced when a charged particle passes close to the surface of a metallic, periodic structure.

$$\lambda = \frac{l}{n}\Big(\frac{1}{\beta} - cos(\Theta)\Big)$$

Smith-Purcell radiation

$$\left(\frac{dI}{d\Omega}\right)_{N_e} \approx \left(\frac{dI}{d\Omega}\right)_1 N_e^2 \left| \int_{-\infty}^{\infty} T e^{-i\omega t} dt \right|^2$$

where N_e -is number of charged particles.



This research dedicated to study of the features of this recovery

Intro

To recover phase $\Theta(\omega)$ from amplitude $\rho(\omega)$ several techniques exist: Kramers-Kronig:

$$\Theta(\omega_0) = \frac{2\omega_0}{\pi} P \int_0^{+\infty} \frac{ln(\rho(\omega))}{\omega_0^2 - \omega^2} d\omega$$

where ω is frequency.
Hilbert:

$$\Theta(\omega_0) = -\frac{1}{\pi} P \int_{-\infty}^{+\infty} \frac{ln(\rho(\omega))}{\omega_0 - \omega} d\omega.$$

or

$$\mathcal{F}(H(u))(\omega) = (-i \ \mathrm{sgn}(\omega)) \cdot \mathcal{F}(u)(\omega)$$

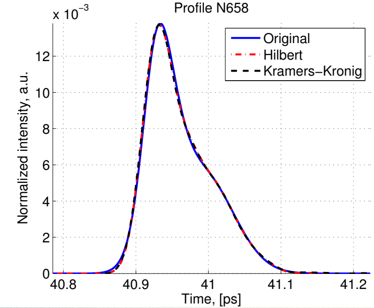
where $\mathcal{F}$ is Fourier transform.

Simulation

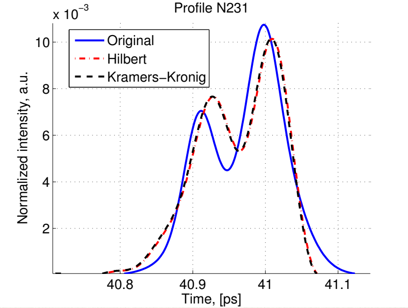
- Profile generator (sum of 5 gaussians)
- Sampling: (Linear, Triple sine, Log)
- Restore of spectrum (interpolation (PCHIP) and extrapolations (Gaussian for LF and Ae^B for HF))
- Restore of phase (Hilbert, Kramers-Kronig)
- Restore of position and direction (based on minimum of χ^2)

Results

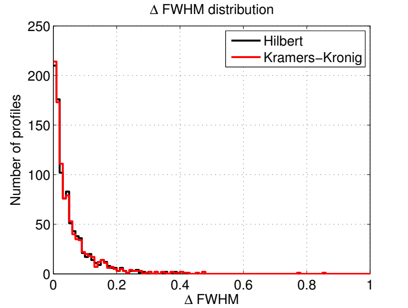
Good

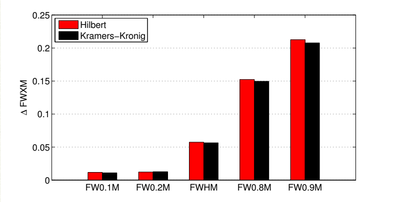


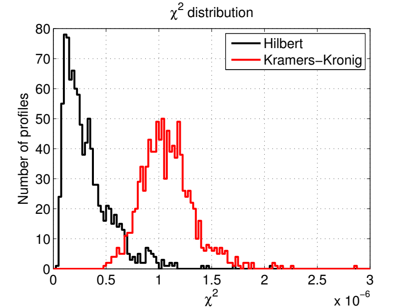
Bad



Results

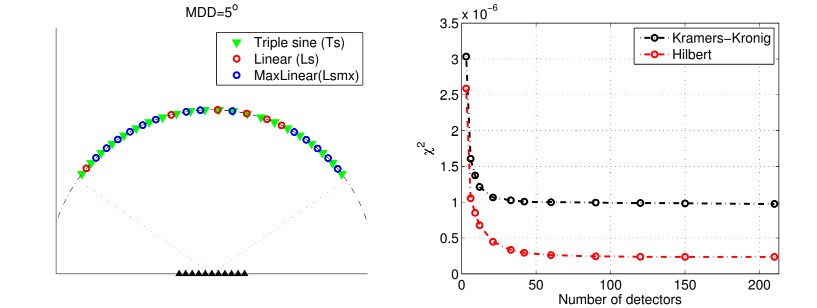






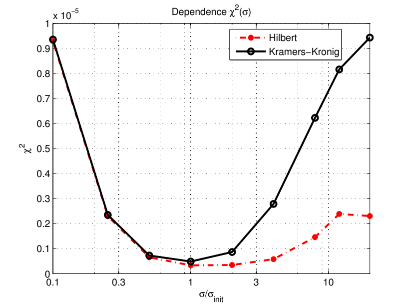
- $\Delta_{FWXM} = \left| \frac{FWXM_{\text{orig}} - FWXM_{\text{reco}}}{FWXM_{\text{orig}}} \right|$
- At different hight of profile there is different quality of reconstruction
- Hilbert method works better and faster (0.02 s vs. 1m for KK)

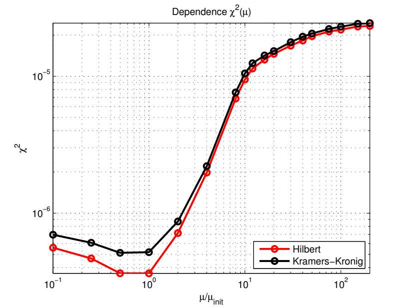
Results



- Linearly sampled points give best reconstuction, but impossible due to space consideration
- 33 sampled points (current setup) is quite optimal

Stability of reconstruction

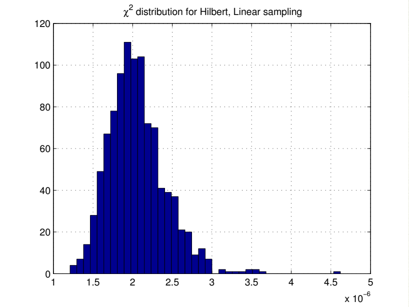


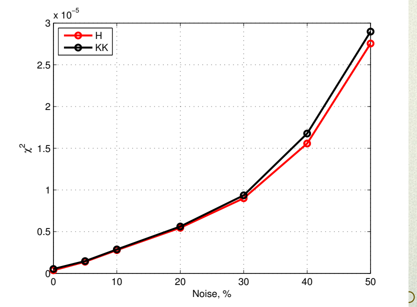


To ensure that the choice of the parameters σ_i and μ_i (from Profile generator) for the simulations does not bias significantly the results, their value has been varied as shown at figures left

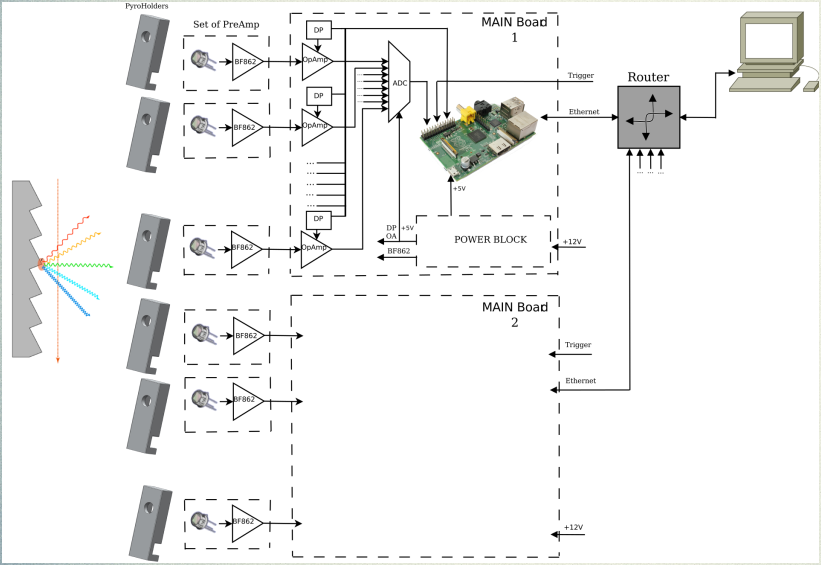
Stability of reconstruction

- Lorenzian are also well reconstructed
- For small noise value, impact of it in reconstruction is quite low.





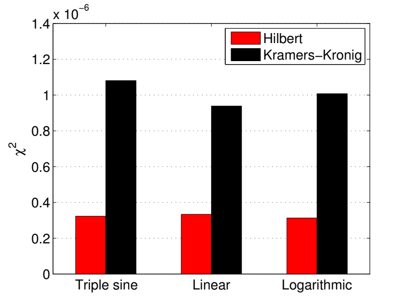
DAQ for SP at Frascati

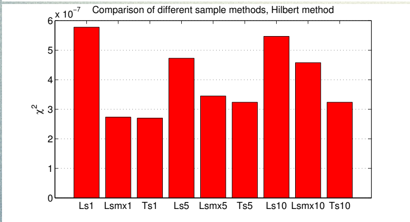


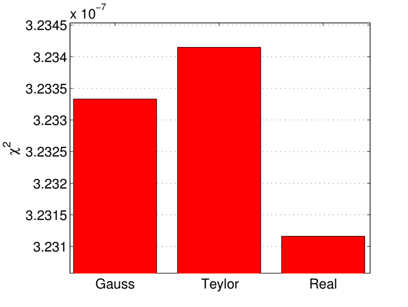
End

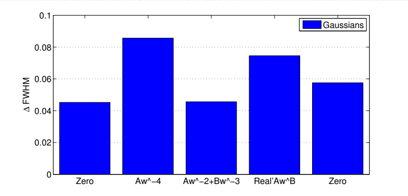
Thank You!

Simulation

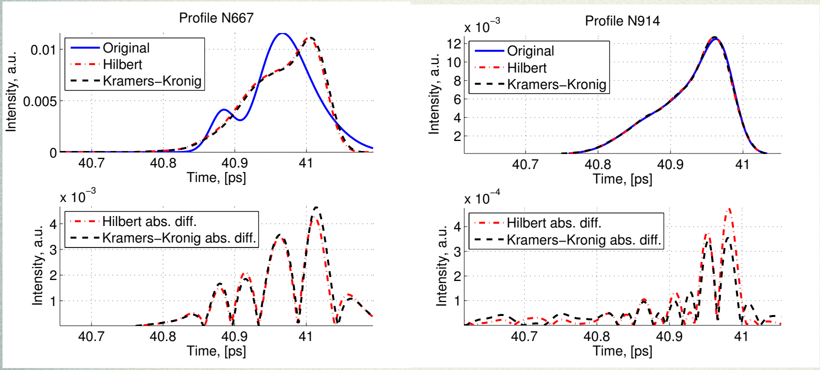

x 10^−6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
χ^2
Hilbert
Kramers−Kronig
Triple sine
Linear
Logarithmic


x 10^−7
Comparison of different sample methods, Hilbert method
6
5
4
3
2
1
0
χ^2
Ls1
Lsmx1
Ts1
Ls5
Lsmx5
Ts5
Ls10
Lsmx10
Ts10


x 10^−7
3.2345
3.234
3.2335
3.233
3.2325
3.232
3.2315
3.231
χ^2
Gauss
Teylor
Real

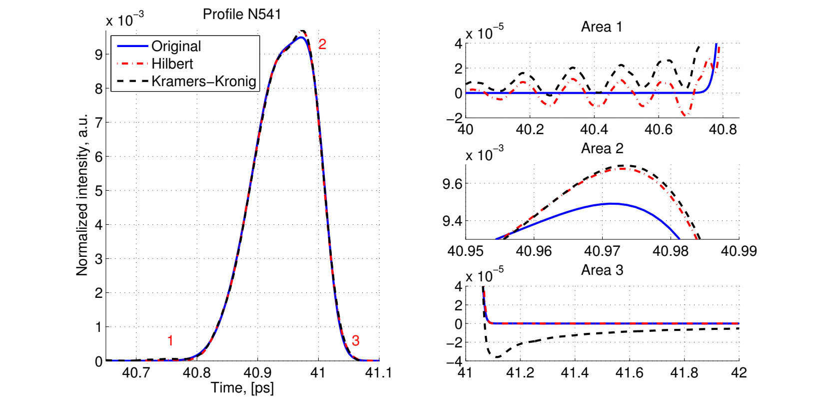

0.1
0.08
0.06
0.04
0.02
0
Δ FWHM
Gaussians
Zero
Aw^−4
Aw^−2+Bw^−3
Real'Aw^B
Zero

Results



Profile N667
Intensity, a.u.
0.01
0.005
0
Original
Hilbert
Kramers–Kronig
40.7
40.8
40.9
41
Time, [ps]
x 10^{-3}
Hilbert abs. diff.
Kramers–Kronig abs. diff.
Profile N914
x 10^{-3}
12
10
8
6
4
2
x 10^{-4}

Results



Profile N541
x 10^−3
Normalized intensity, a.u.
Time, [ps]
Original
Hilbert
Kramers–Kronig
1
2
3
40.7
40.8
40.9
41
41.1
Area 1
x 10^−5
40
40.2
40.4
40.6
40.8
Area 2
x 10^−3
9.6
9.4
40.95
40.96
40.97
40.98
40.99
Area 3
x 10^−5
41
41.2
41.4
41.6
41.8
42

DAQ