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Comparison between FBP and SART for digital tomosynthesis for PCB inspection

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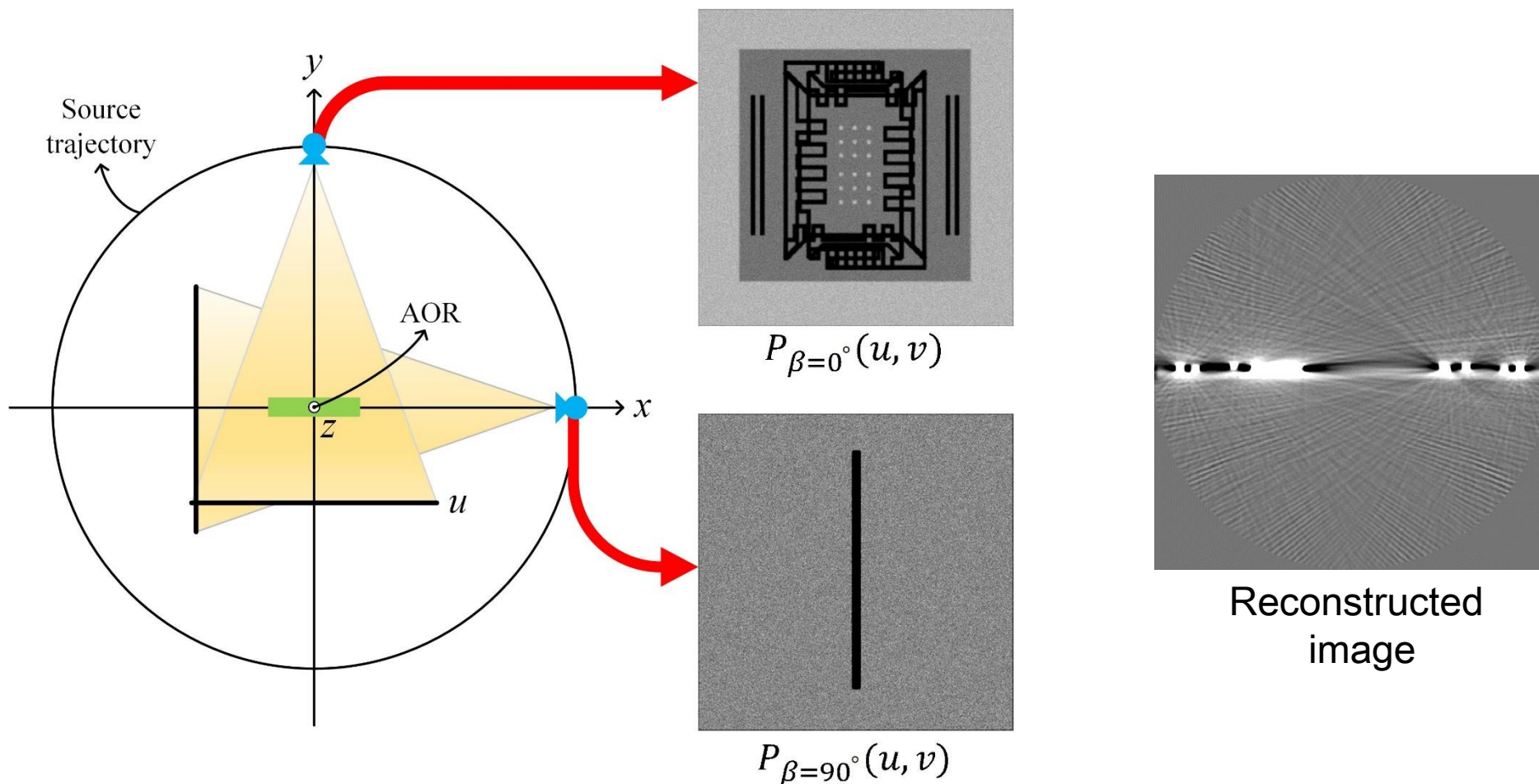
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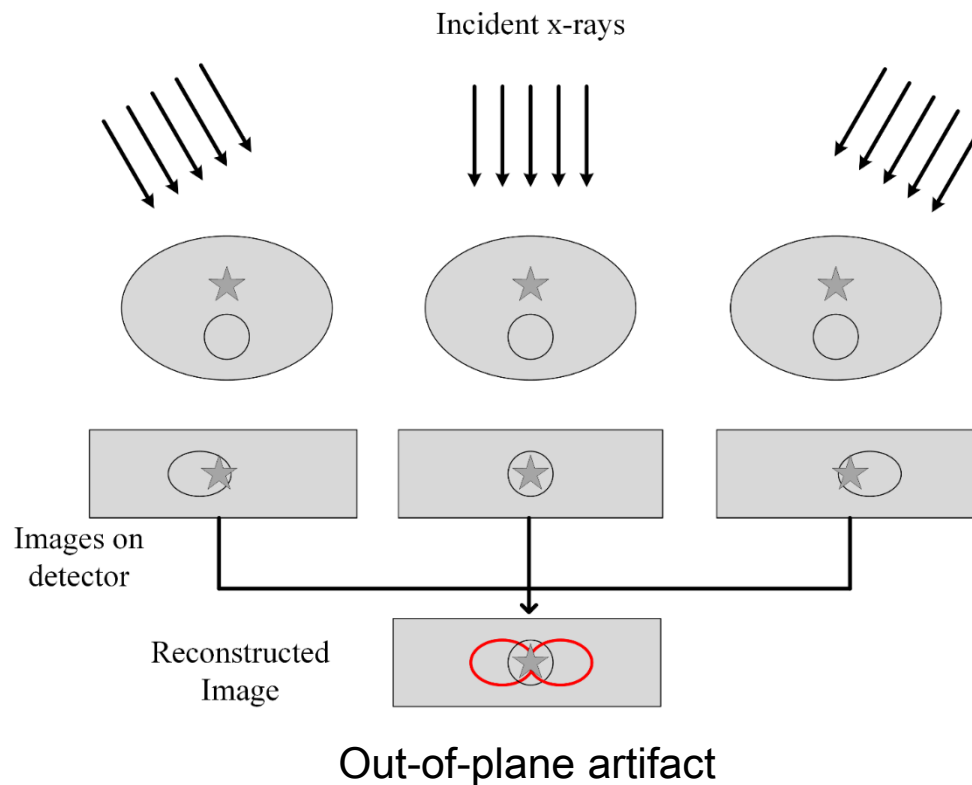
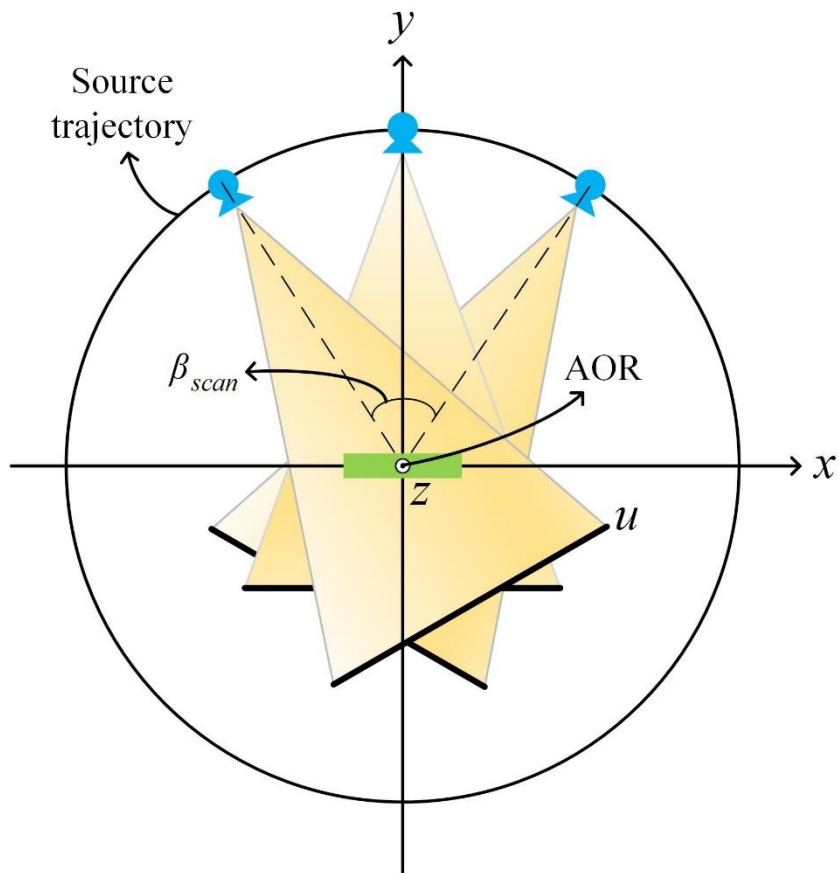
Introduction

- Computed tomography(CT) for PCB inspection

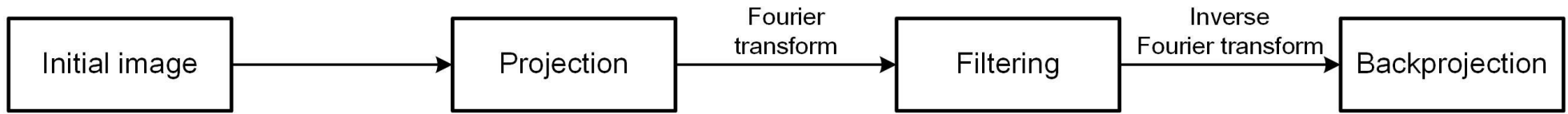


Introduction

- Digital tomosynthesis(DTS) for PCB inspection



Filtered backprojection



weight

projection

filter

$$f(x, y; z) = \int_{\beta_{\min}}^{\beta_{\max}} \frac{d_{SD}^2}{(d_{SO}-s)^2} \int_{-\infty}^{\infty} \frac{d_{SD}}{\sqrt{d_{SD}^2 + \xi^2 + \eta^2}} p(\xi, \eta; \beta) h(\xi - \xi') d\xi d\beta \quad ^1)$$

filtering

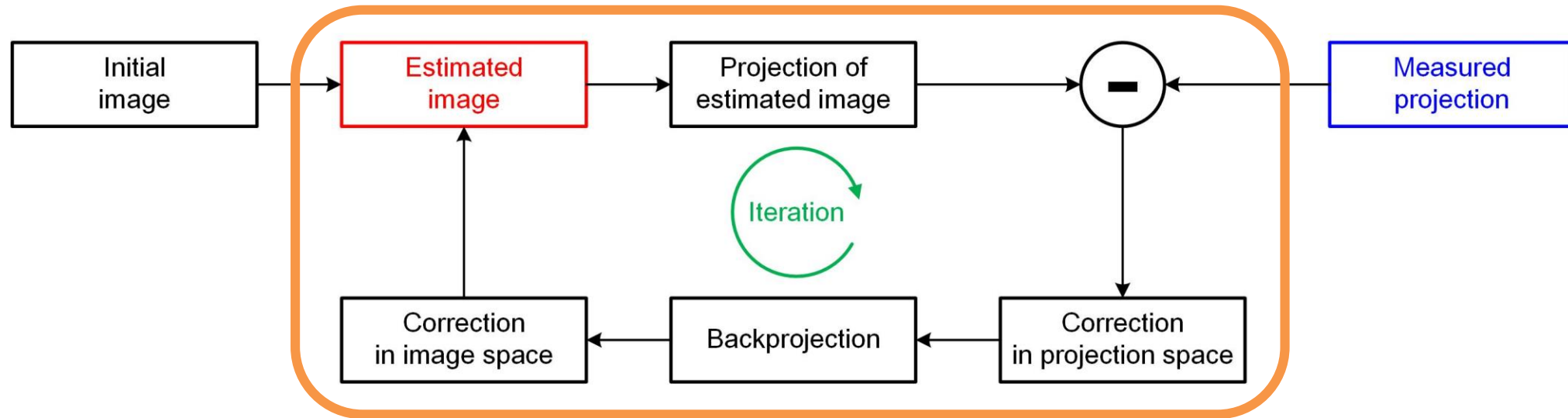
backprojection

- Slice thickness filter

- $H_{ST}(w) = \frac{1}{2} \left[1 + \cos\left(\frac{\pi w}{k_{ST}}\right) \right]$

Simultaneous algebraic reconstruction technique

- $Af = p$



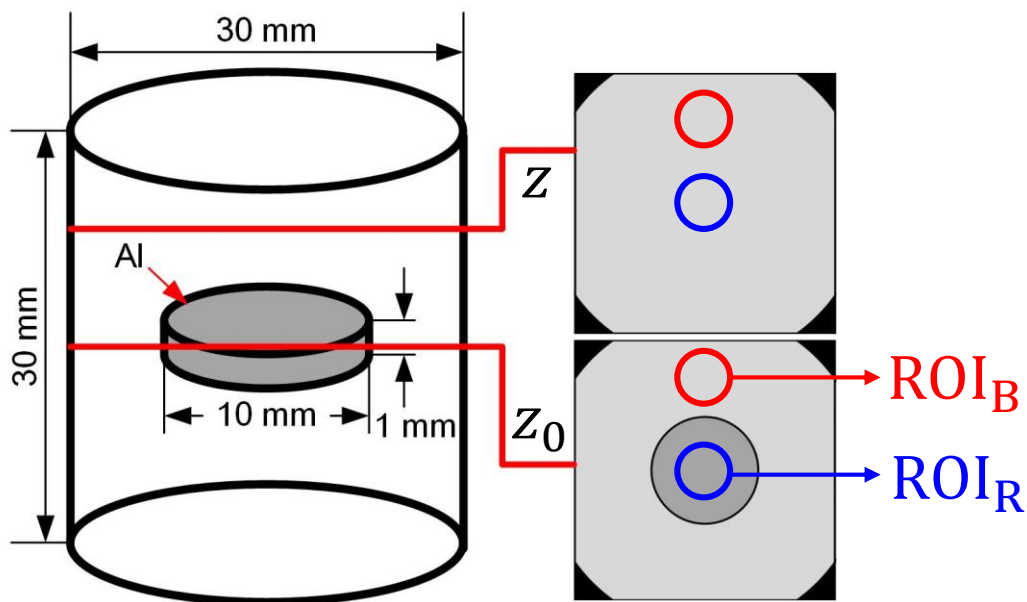
- $$f^{(i+1)} = f^{(i)} + \frac{\sum \left[a_j \frac{p_j - \vec{a}_j^T f^{(i)}}{\sum a_j} \right]}{\sum a_j} \quad 2)$$

Stopping criterion

- $$\frac{\frac{1}{N} \sum \sum \sum |f^{(i)} - f^{(i+1)}|}{\frac{1}{N} \sum \sum \sum |f^{(i)}|}$$

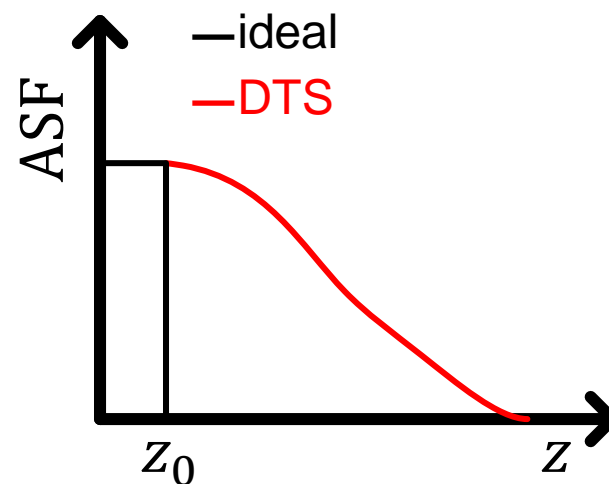
Disc impulse response

- Artifact spread function (ASF)
- Signal difference-to-noise ratio (SDNR)

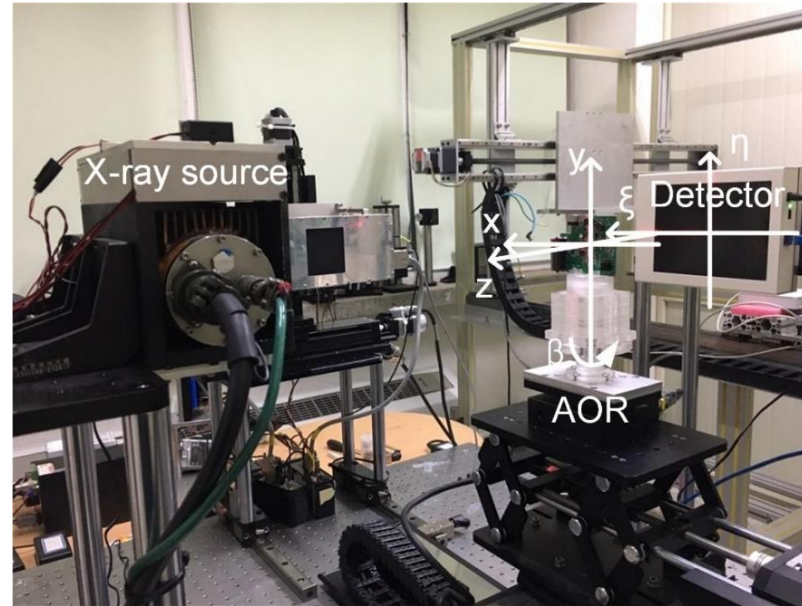


$$SDNR = \frac{S_R(z_0) - S_B(z_0)}{\sigma_B(z_0)}$$

$$ASF = \frac{S_R(z) - S_B(z)}{S_R(z_0) - S_B(z_0)}$$



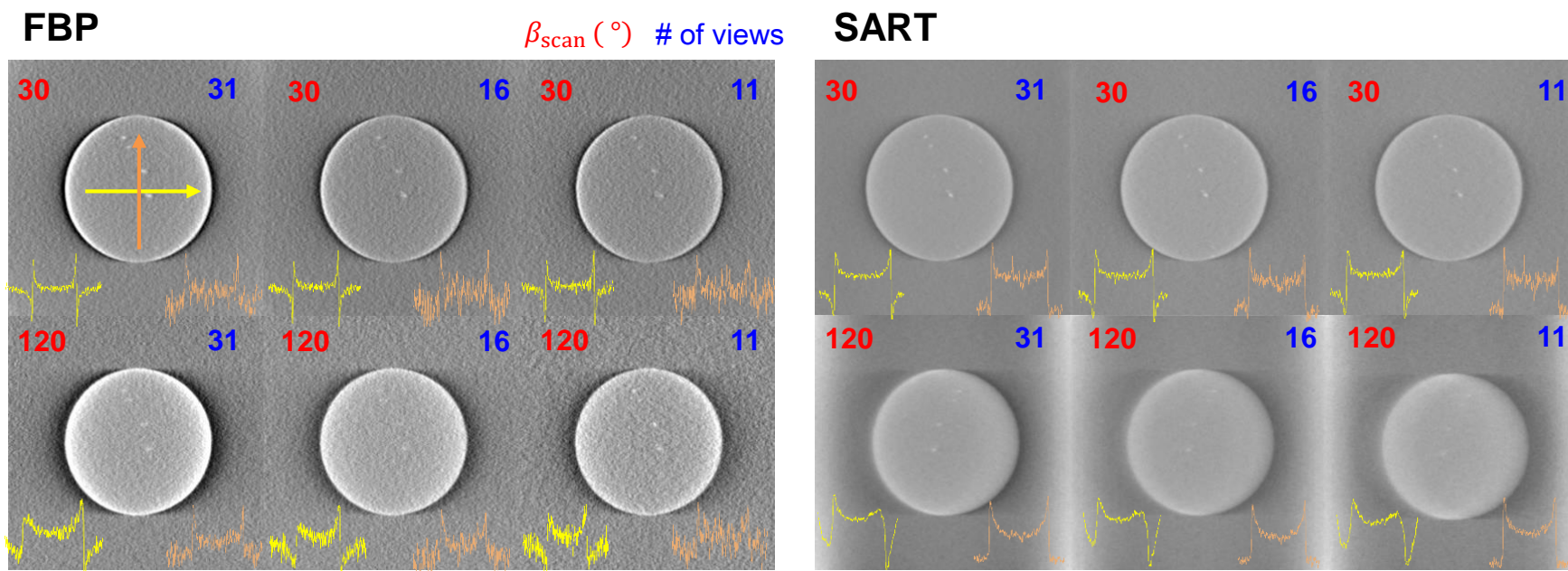
Experimental information



		Al-disc	Reconstruction information				
Beam setup	Added filtration	2 mm (Al)					
	Tube voltage (kV)	45	Scan Angle (°)	30	60	90	120
	Tube current (mA)	0.9					
	Readout time (ms)	200					
Geometrical setup		SDD (mm)					
	SOD (mm)	307.5	Step Angle (°)	1,2,3,5	1,2,4,6	3,6,9	4,8,12
	Magnification	2					
	Detector size	1548×1032/ 0.099×0.099 (mm ²)					

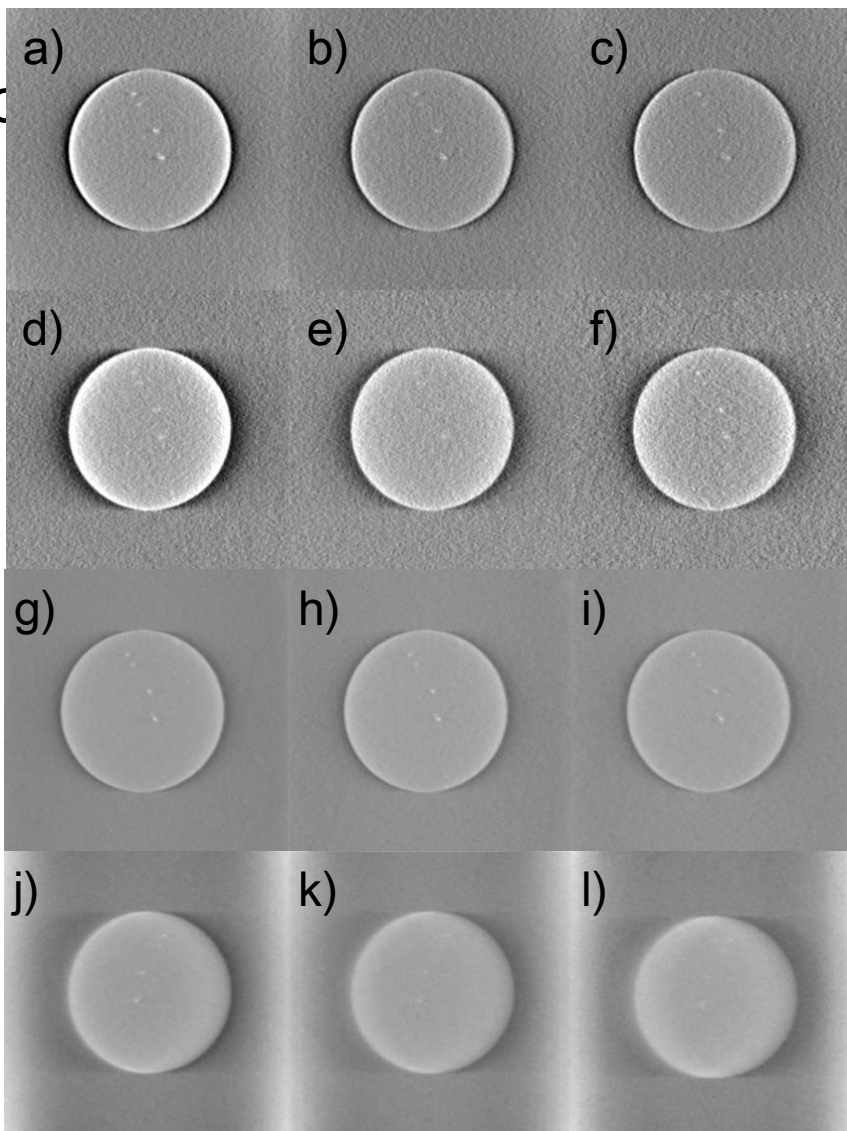
Disc images

- Reconstructed images at plane of interest



Disc images

- Rec

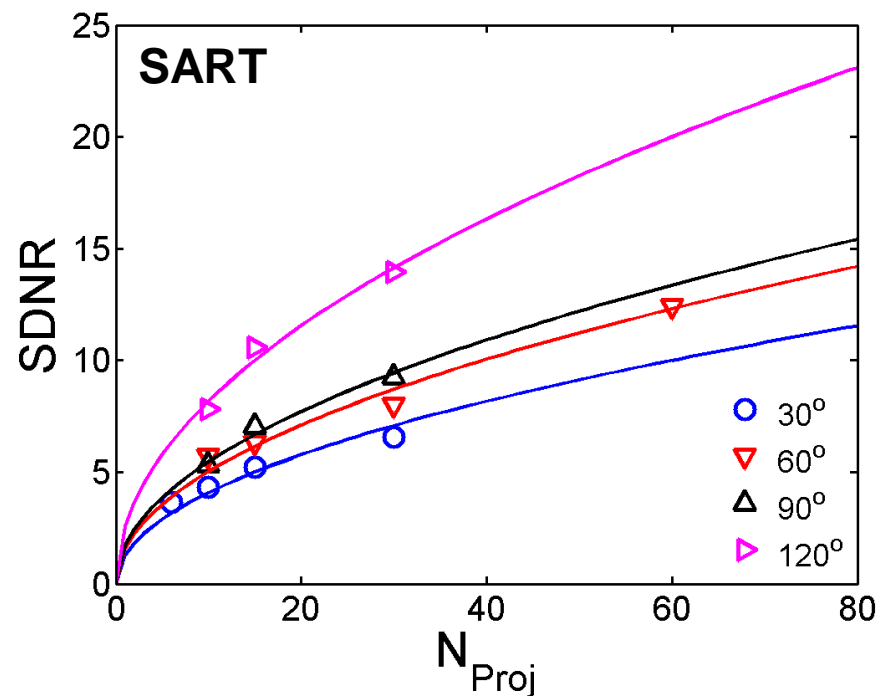
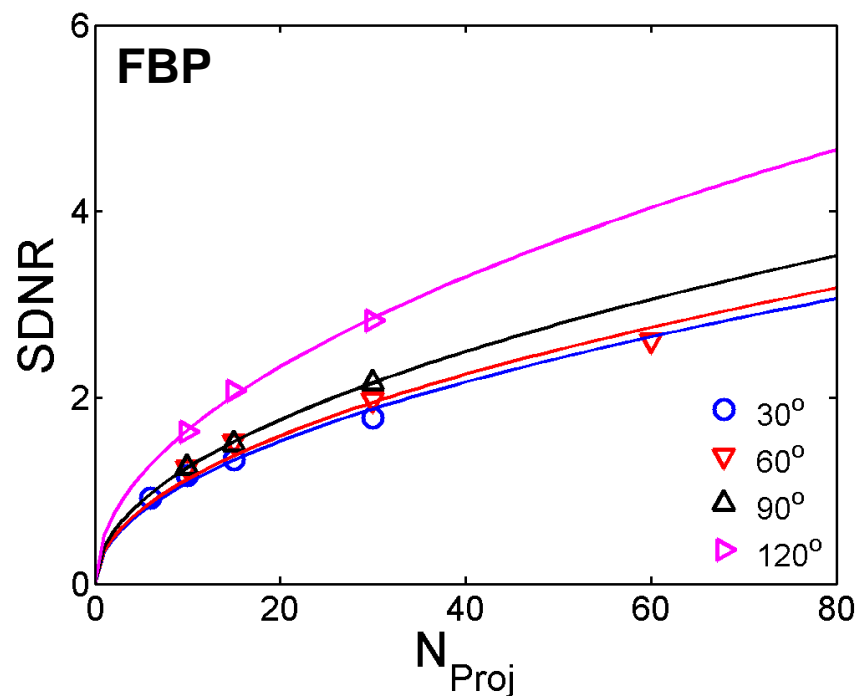


of interest

FBP

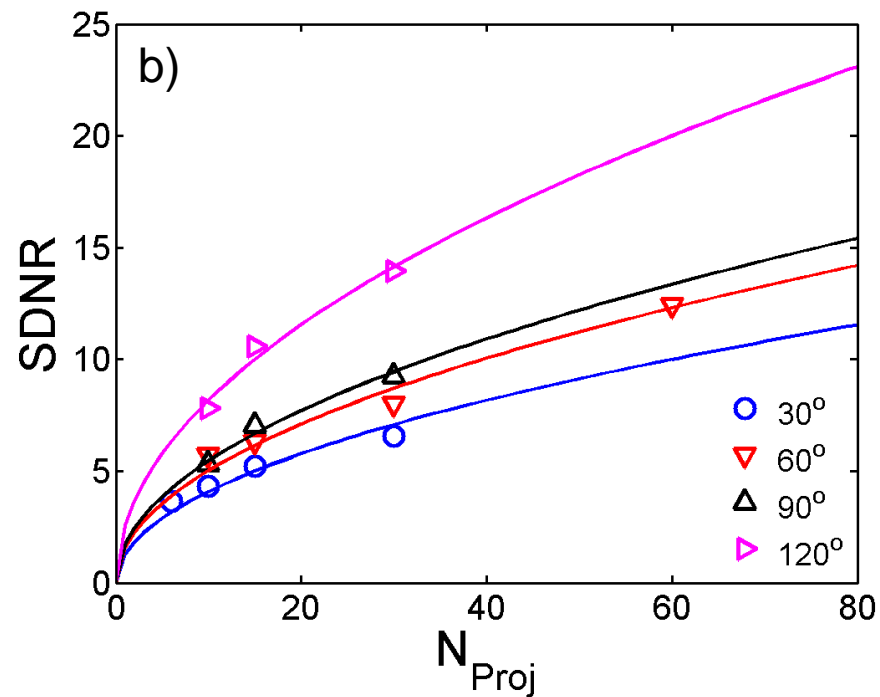
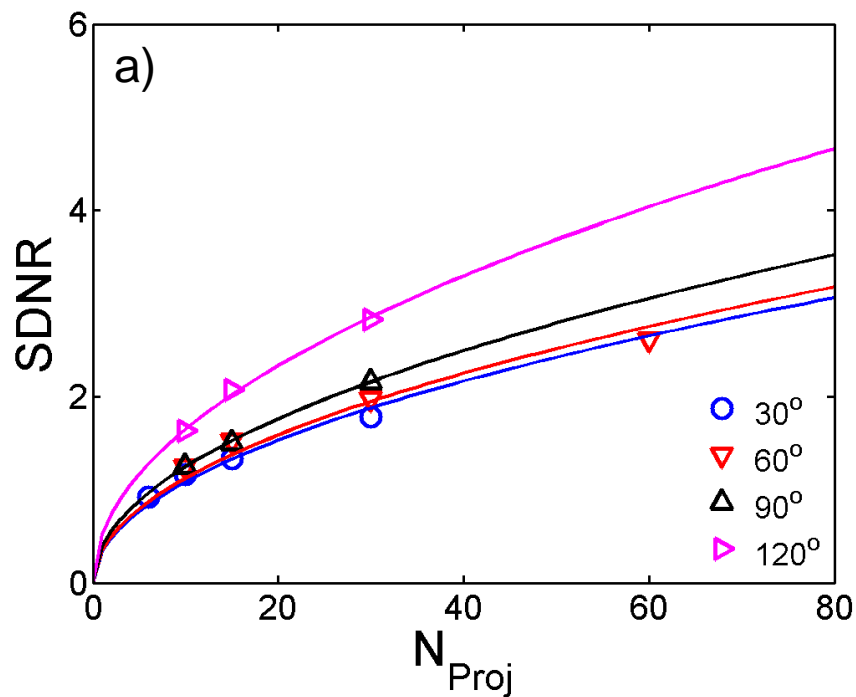
SDNR

- SDNR results for various scan angles at plane of interest



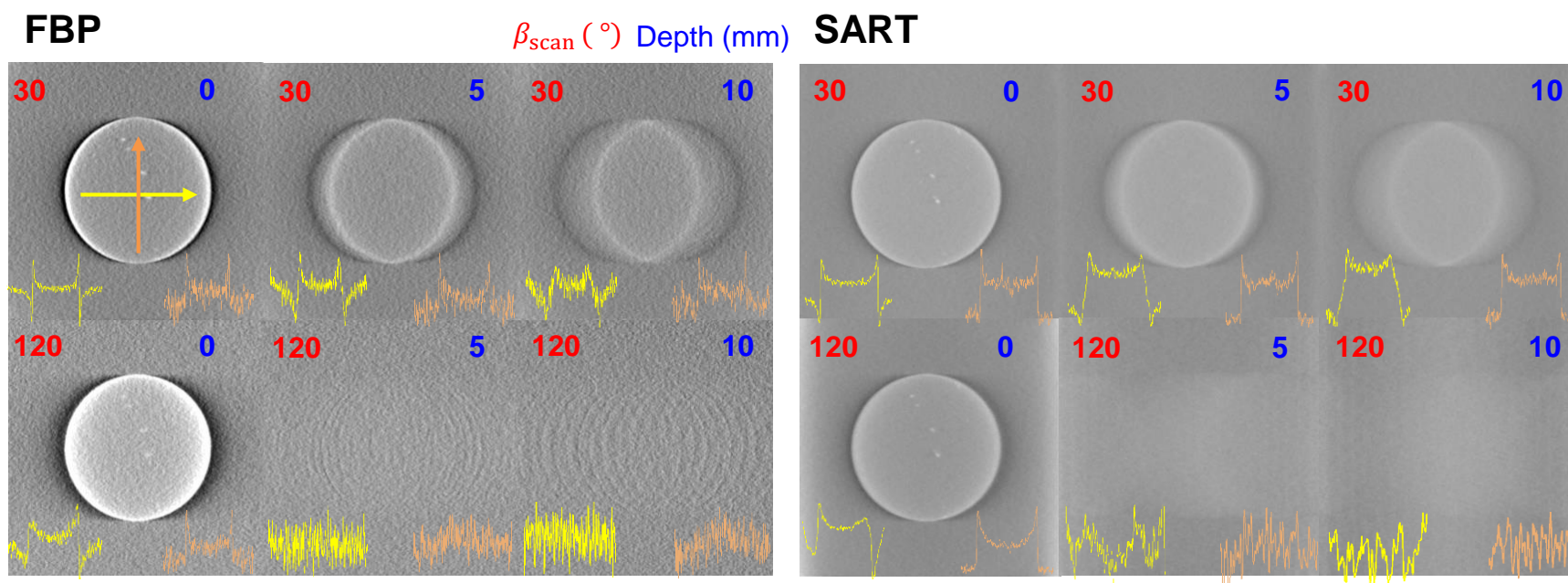
SDNR

- SDNR results for various scan angles at plane of interest



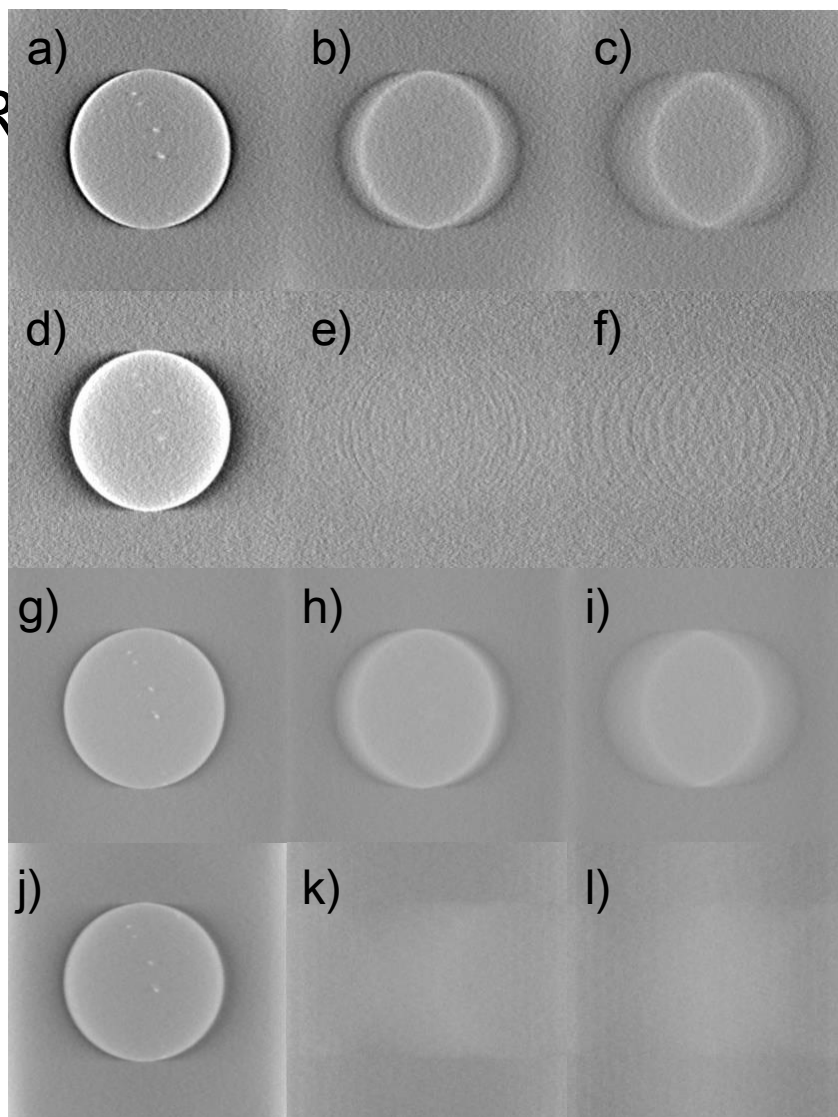
Disc images

- Reconstructed images along the depth (z) direction



Disc images

- R

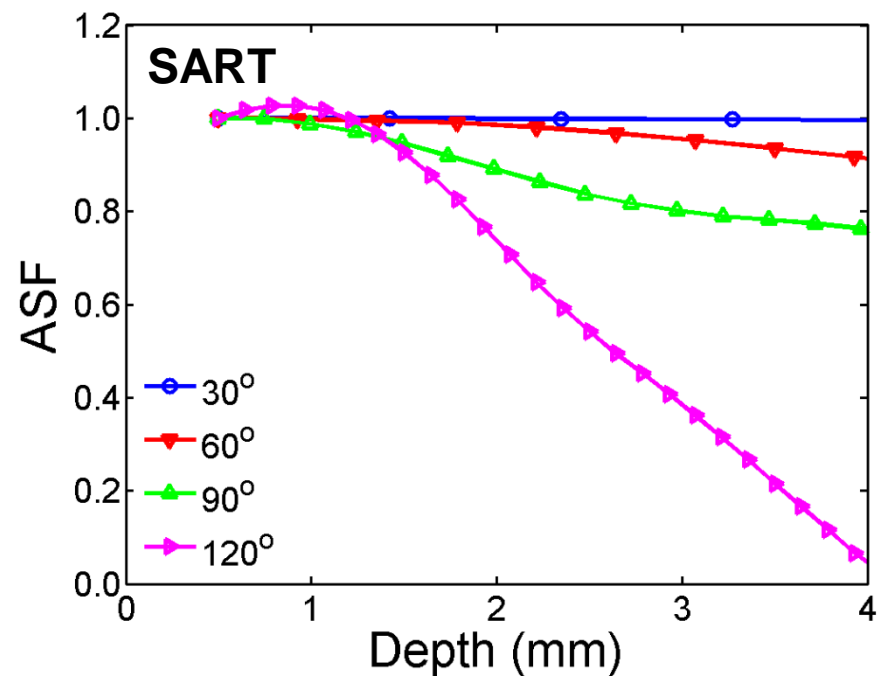
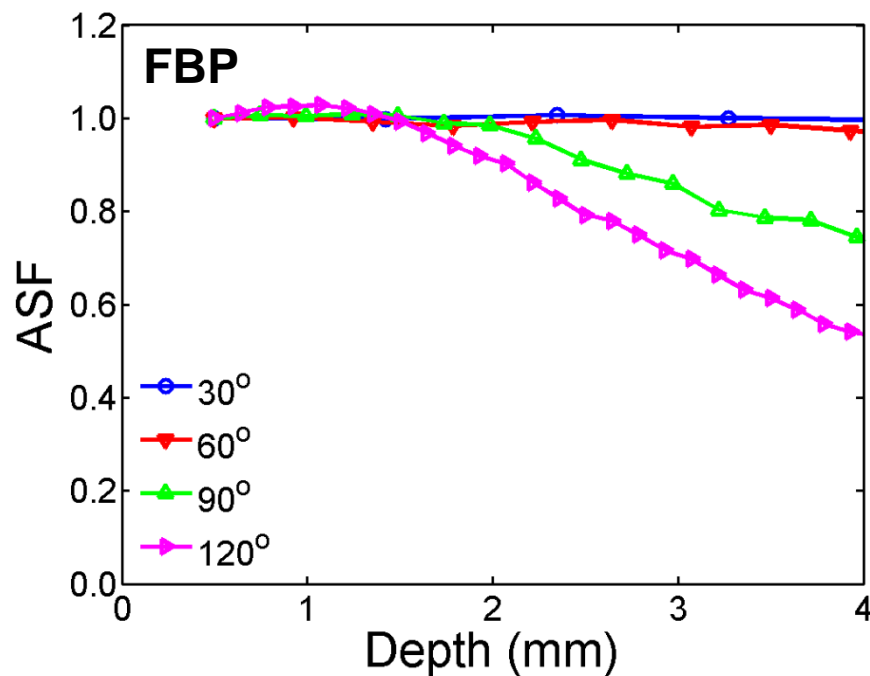


the depth (z) direction

SART

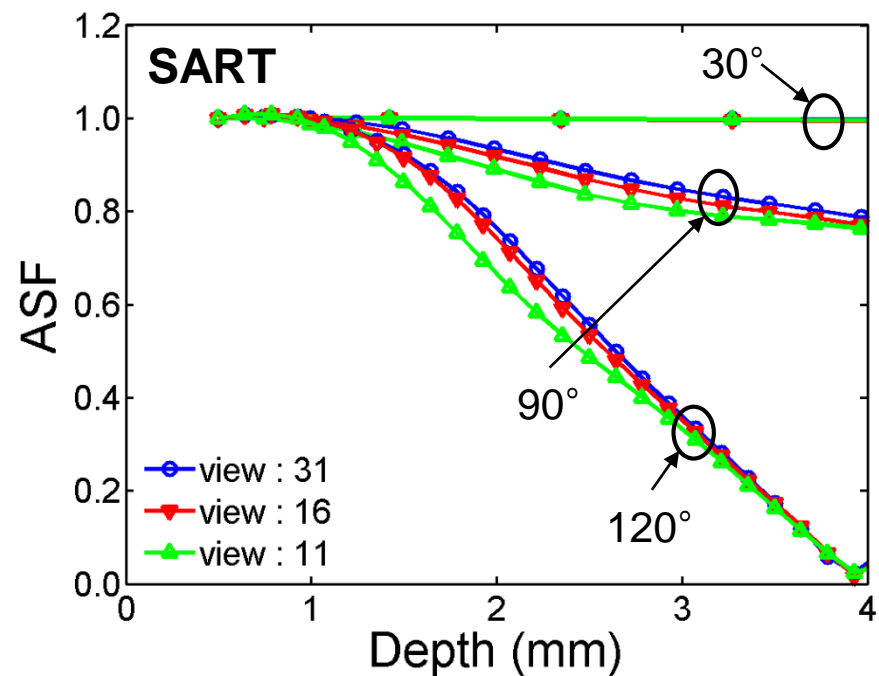
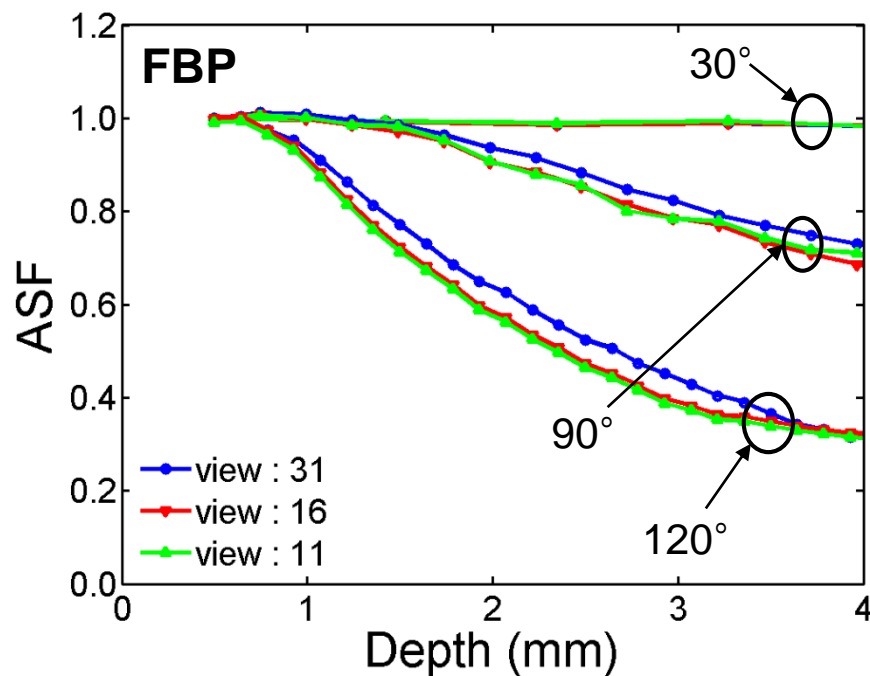
ASF

- ASF results for various scan angles with 11 views



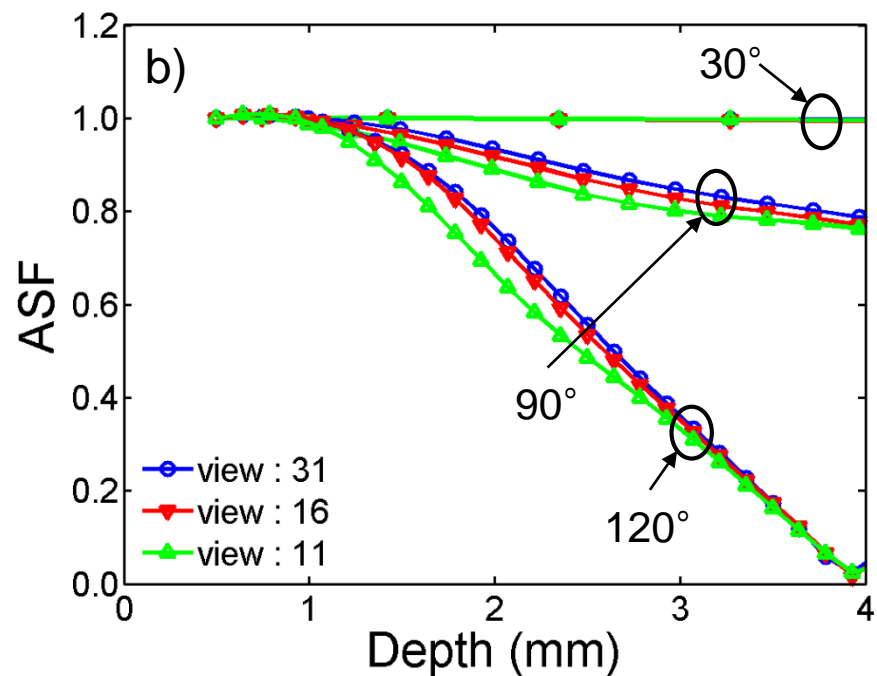
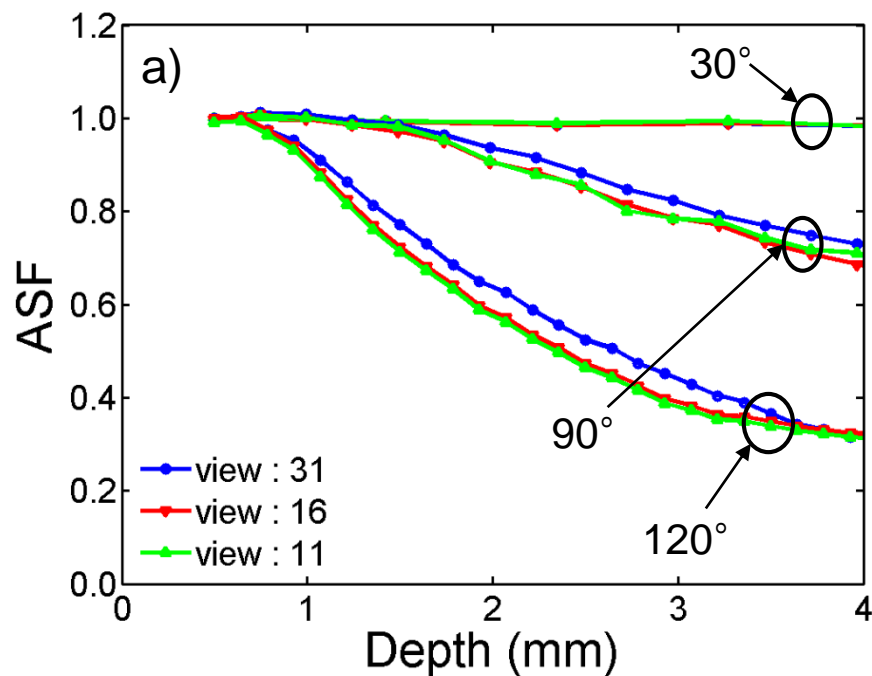
ASF

- ASF results for various scan angles with various views



ASF

- ASF results for various scan angles with various views



Discussion

- Structural Similarity (SSIM)

- $$\text{SSIM} = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \leq 1$$

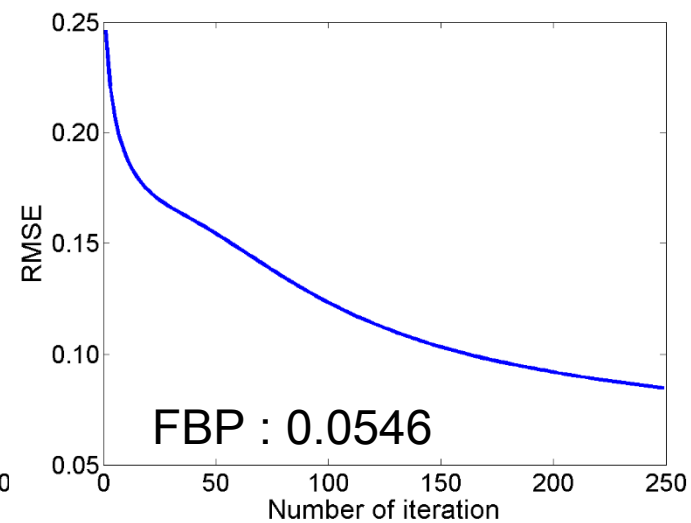
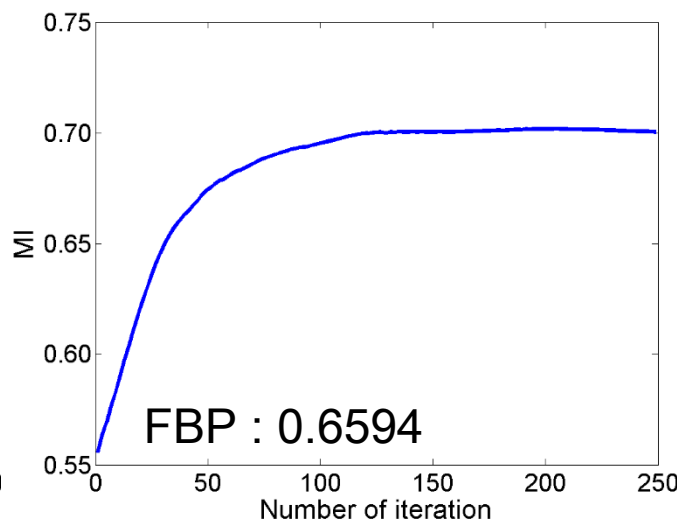
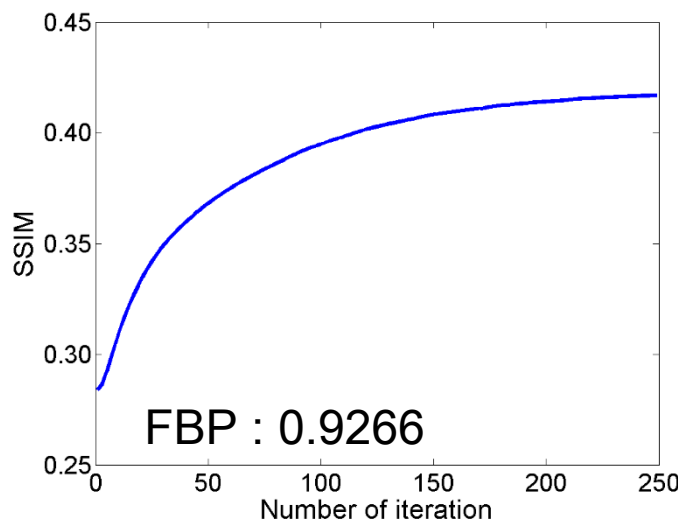
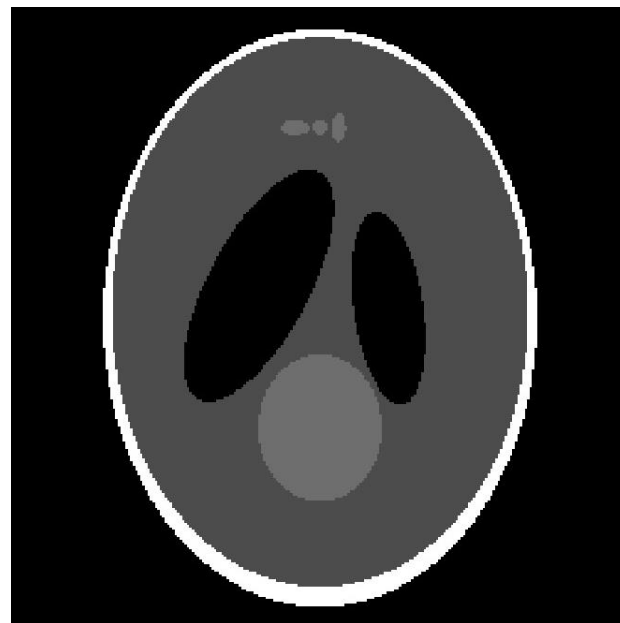
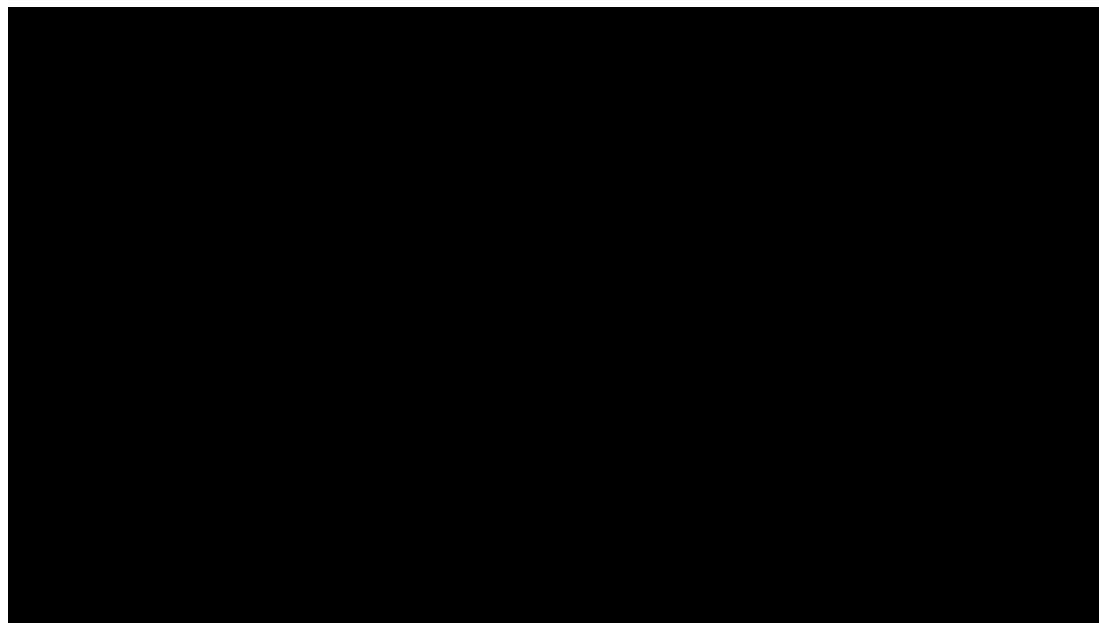
- Mutual information (MI)

- $$\text{MI} = \sum_{y \in Y} \sum_{x \in X} p(x, y) \log_2 \left(\frac{p(x, y)}{p(x)p(y)} \right) \leq 1$$

- Root mean square error (RMSE)

- $$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{n=1}^N (X^{(i)} - X^{(i+1)})^2}$$

Numerical study



Summary

- FBP- and SART-based DTS
 - SDNR increases with $\sqrt{N_{proj}}$
 - SDNR increases with β_{scan}
 - ASF (or the depth resolution) improves with β_{scan}
 - ASF is independent of N_{proj}
- The SART is better than the FBP in both the SDNR & ASF performances
- On the contrary, the numerical study shows that the quality assessment metrics of the FBP is better than those of the SART
- For more quantitative comparisons, the MTF, NPS, and NEQ will be investigated for the two methods