Selection of minimally correlated data for diffuse optical tomography

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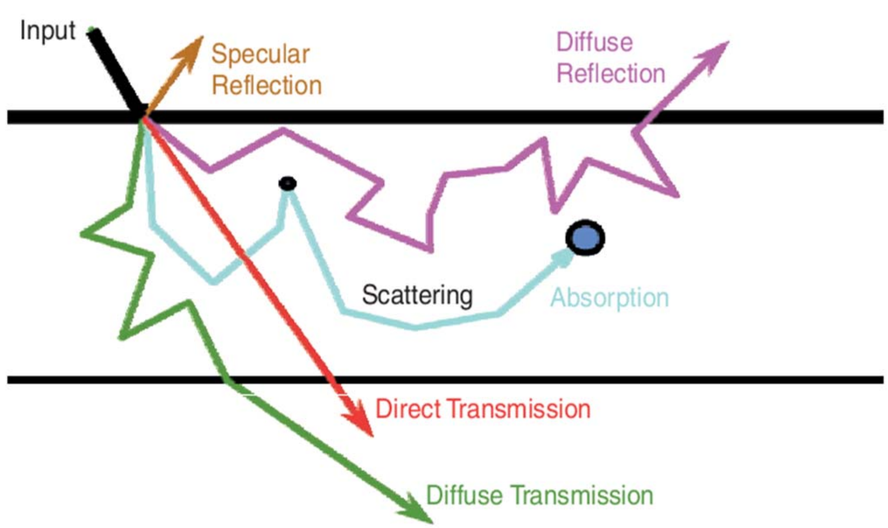
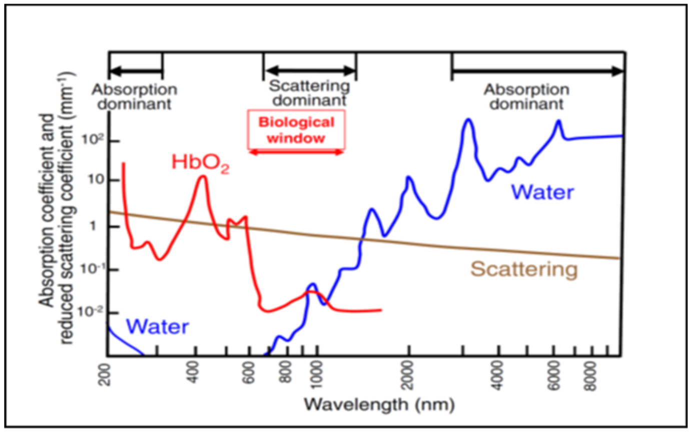
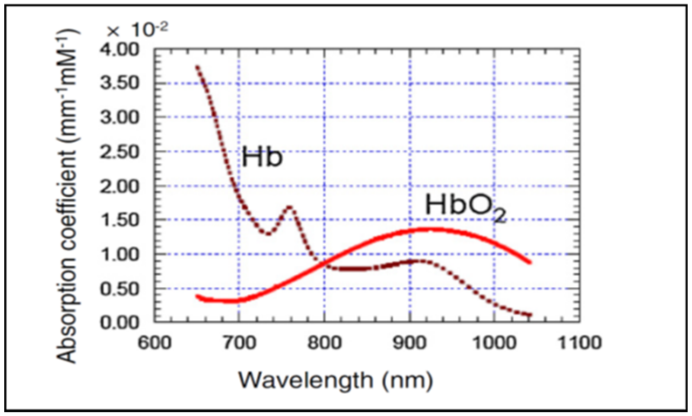
Contents

Introduction

- DOT is emerging imaging modality to provide functional characteristics (oxygen saturation and hemodynamics states) of thick biological tissue.

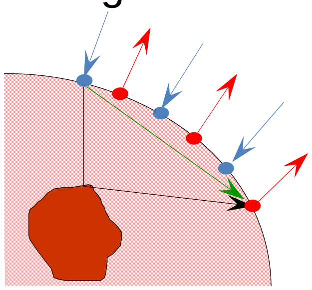




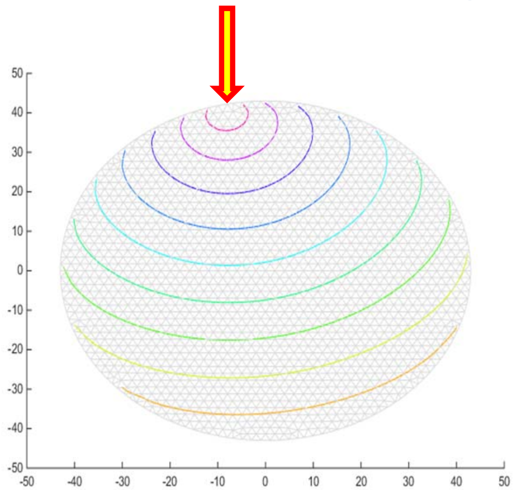


Introduction

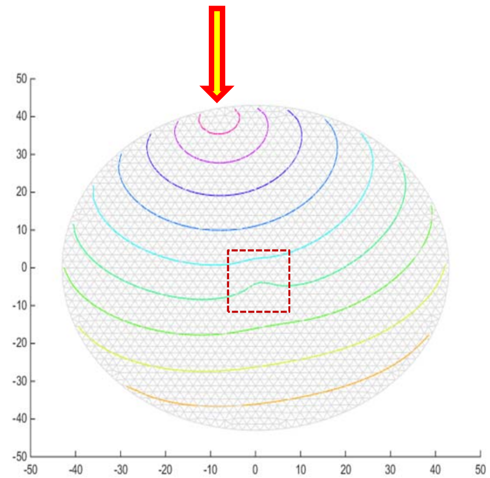
- Finite set of surface intact boundary measurements are made by injecting NIR light through optical fiber bundle arrangements.



(log10) Fluence rate $\left[\frac{1}{mm^2}\right]$



Without target



Circular target of 5mm radius at center

$$-\nabla \cdot D\nabla \Phi(r,\omega)+\left(\mu_a+\frac{i\omega}{c}\right)\Phi(r,\omega)=S_0(r,\omega)$$

Methodology

- Start with the noisy measurements (SD pairs)

$$\phi^{m} = \phi^{c}(\mu) + \psi_{gaussian}$$

- Joint probability density function of the elements of the sample vector ϕ^m

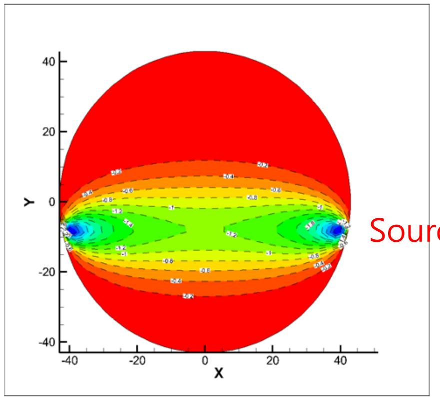
$$p(\phi^m;\mu) = \left(\frac{1}{\sqrt{2\Pi\sigma}}\right)^N \exp\left[-\frac{1}{2\sigma^2}\sum_{n=0}^{N-1}(\phi^m - \phi^c)^2\right]$$

- Under the assumption of uncorrelated measurement noise and similar statistical properties

$$FIM_{ij} = E\left\{\frac{\partial \ln p(\phi^m;\mu)}{\partial \mu_i} \cdot \frac{\partial \ln p(\phi^m;\mu)}{\partial \mu_j}\right\}$$

simplified to, $$FIM = \frac{1}{\sigma^2}[J^T J]$$

where, $$J = \frac{\partial \phi^c}{\partial \mu}$$



Methodology

- Solve the eigen value problem to rank the SD pairs and iteratively delete the least contributed measurements to the linear independence of the unknown parameter

$$[FIM_{REG} - \alpha I]\psi = 0$$

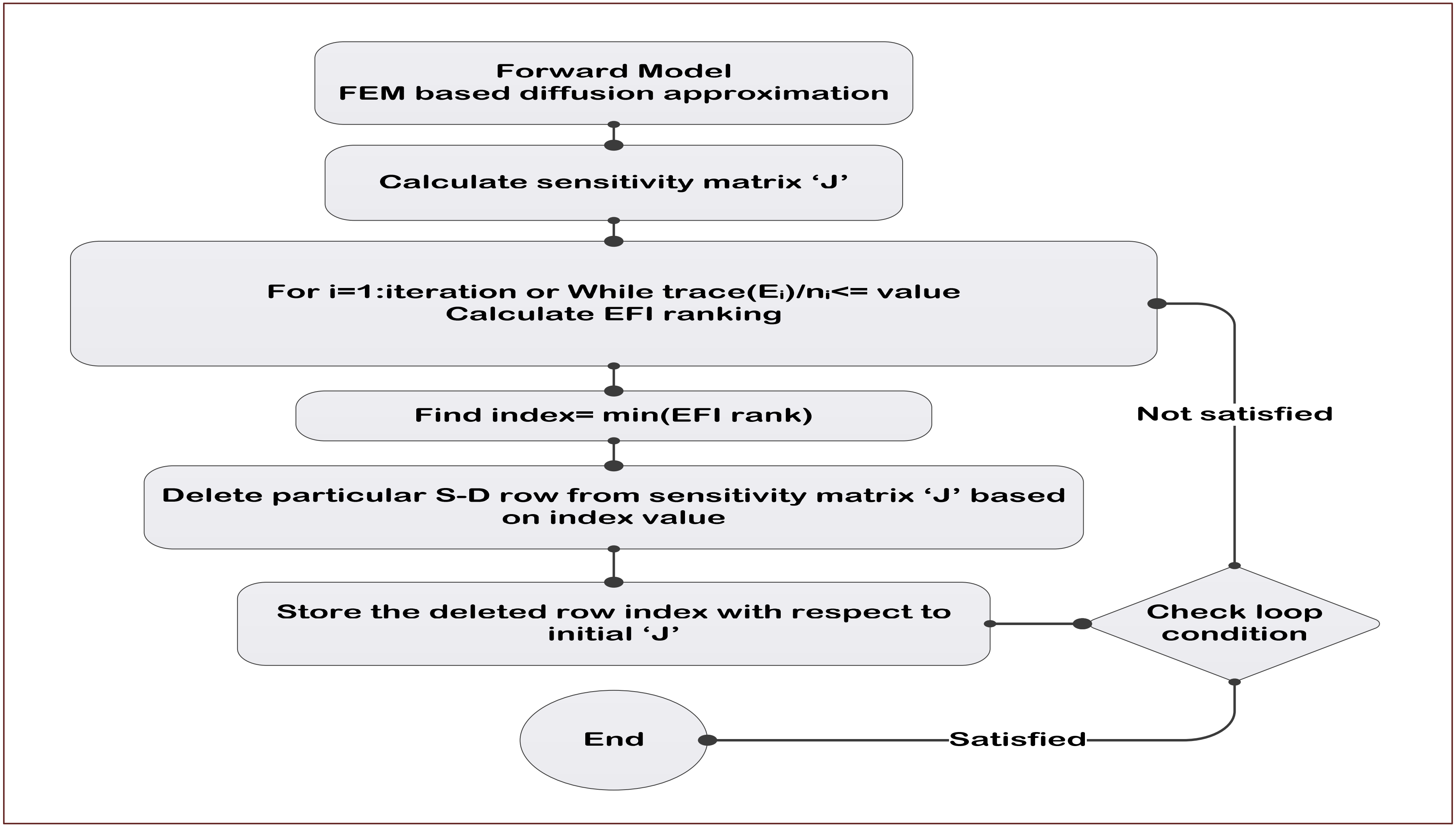
- Fractional eigen value matrix

$$FE = [J\psi] \otimes [J\psi]\alpha^{-1}$$

- Eigen distribution vector

$$ED = \left[\sum_{j=1}^{k} FE_{1j} : \sum_{j=1}^{k} FE_{2j} :\ldots\ldots\ldots\ldots : \sum_{j=1}^{k} FE_{sj} \right]^T$$

Methodology

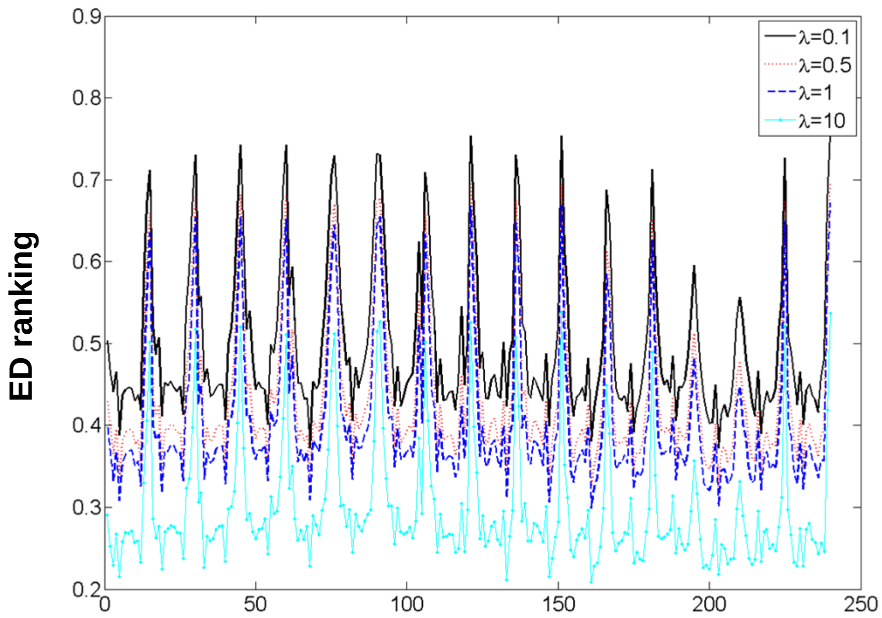


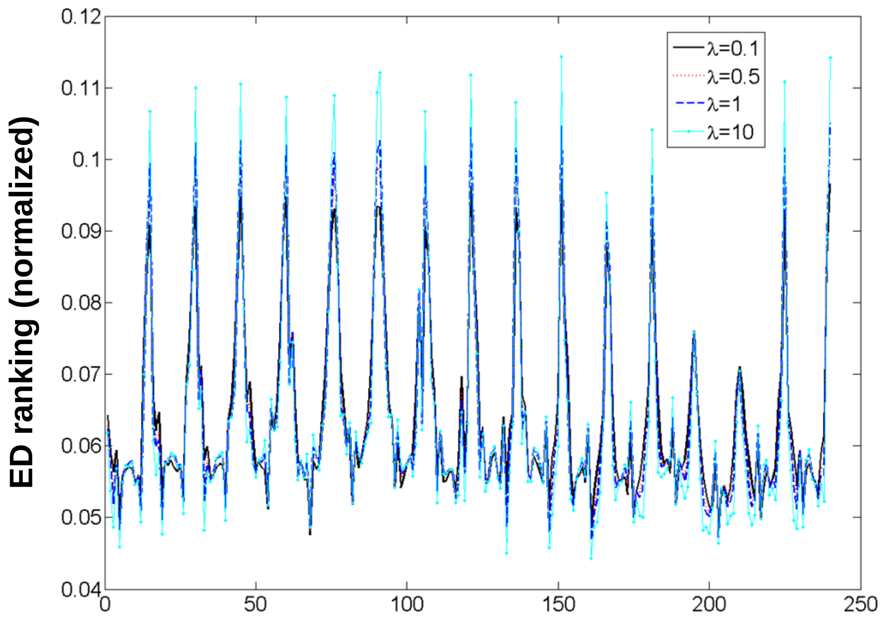
Numerical Simulation

- 2-D circular geometry
  - Radius: 43 mm
  - Target radius: 10 mm
- Single wavelength simulation with 70MHz frequency modulation.
- Forward Mesh
  - #of nodes : 1785
  - #of triangular elements: 3419
- Inverse Mesh
  - Pixel basis [30 30]
- # of measurements (SD pairs): 240
- Optical contrast
  - Homogenous background: ($\mu_a = 0.01\ mm^{-1}$, $\mu_s = 1\ mm^{-1}$)
  - Target: ($\mu_a = 0.02\ mm^{-1}$, $\mu_s = 1\ mm^{-1}$)

Results

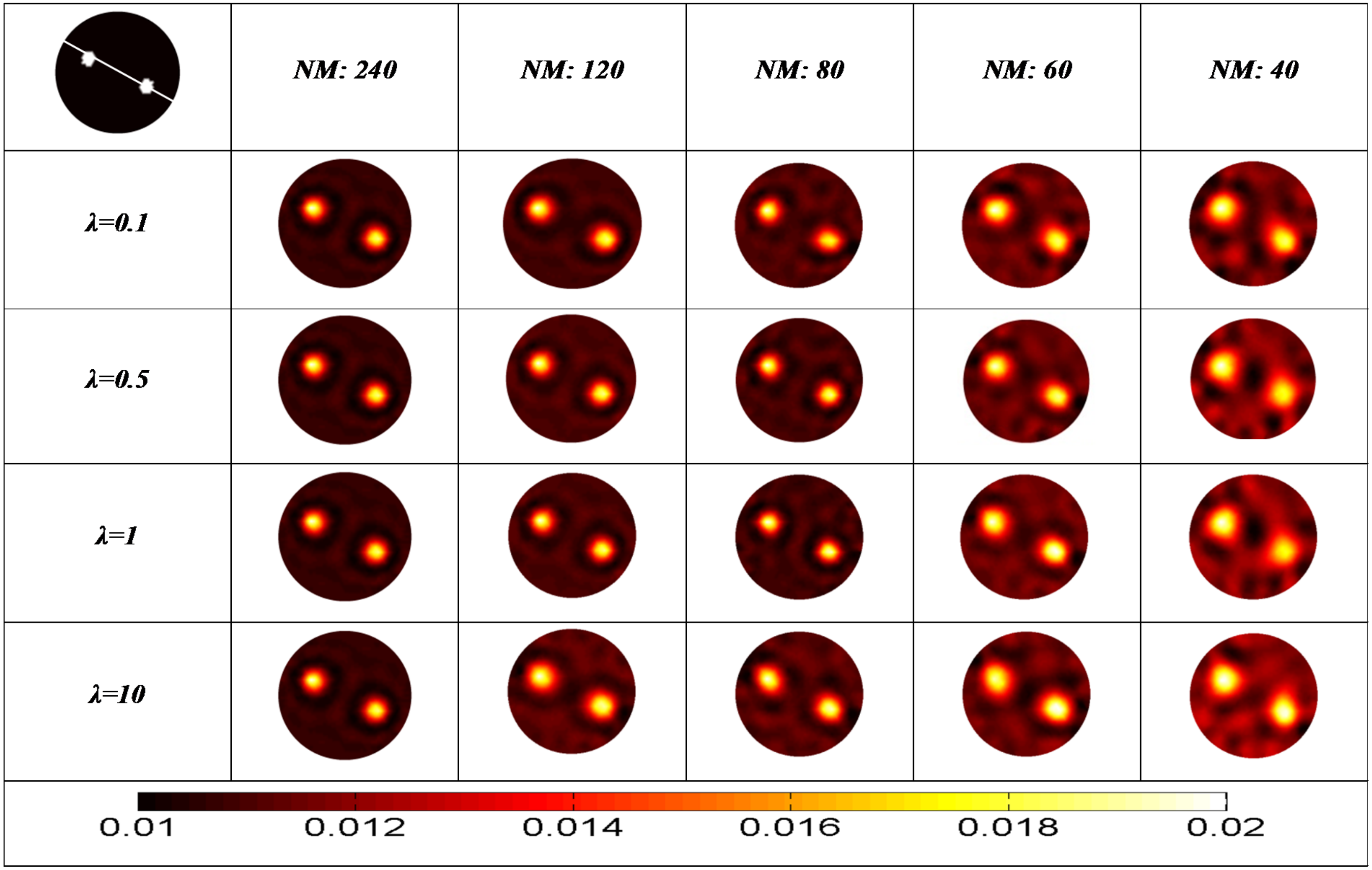
- Dependence of ED vector on regularization parameter





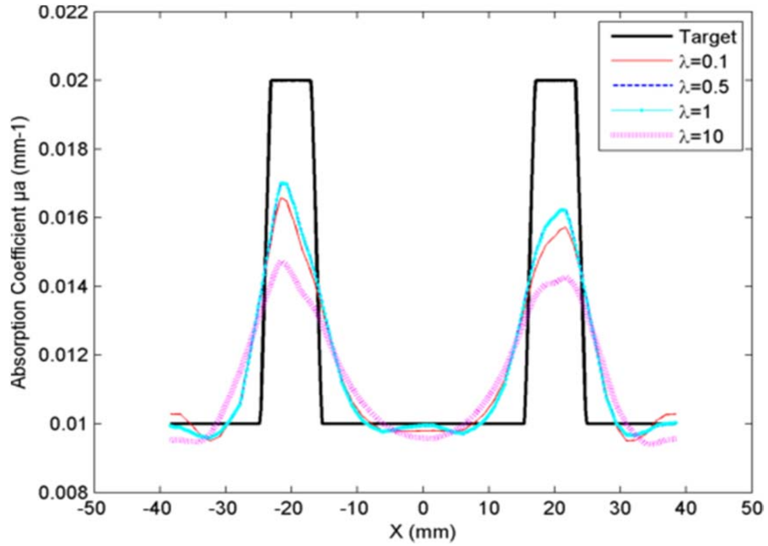
	λ=0.1	λ=0.5	λ=1	λ=10
Min value measurement index	203	203	203	161, 203
Max value measurement index	240	240	240	151,240

Results

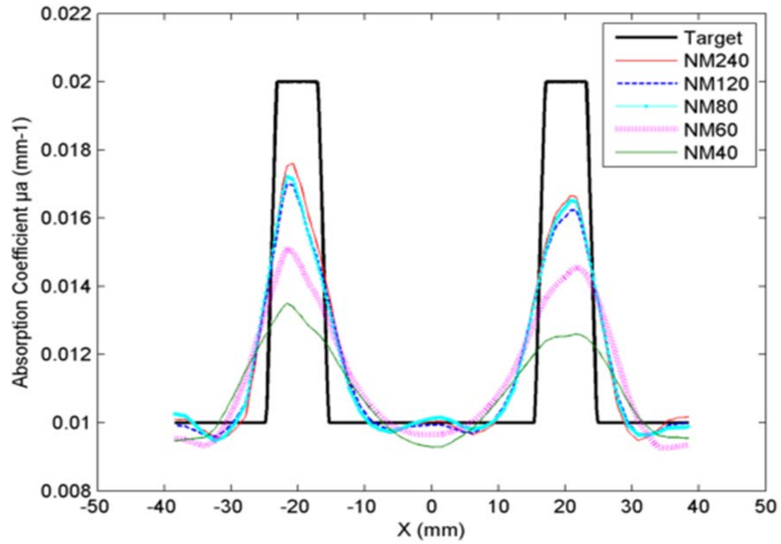


NM: 240
NM: 120
NM: 80
NM: 60
NM: 40
λ=0.1
λ=0.5
λ=1
λ=10
0.01
0.012
0.014
0.016
0.018
0.02

Results



Target
λ=0.1
λ=0.5
λ=1
λ=10
Absorption Coefficient μa (mm-1)
X (mm)
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
-50 -40 -30 -20 -10 0 10 20 30 40 50



Target
NM240
NM120
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Absorption Coefficient μa (mm-1)
X (mm)
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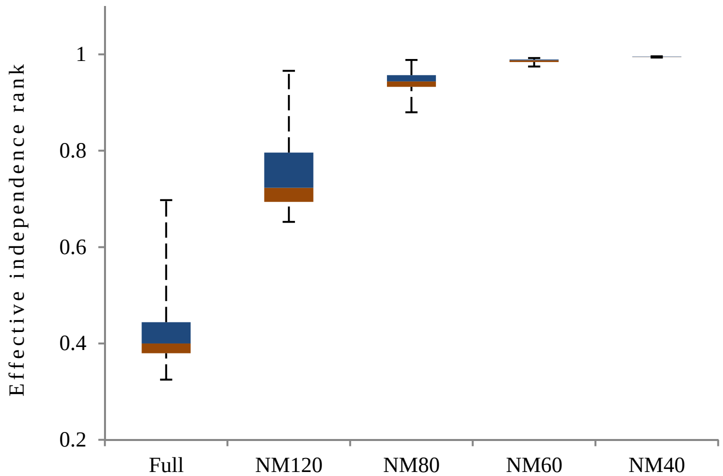

Effective independence rank
1
0.8
0.6
0.4
0.2
Full
NM120
NM80
NM60
NM40

Conclusions

- Results demonstrated that similar contrast recovery is possible for optimized sparse configuration of SD pairs compared with the dense configuration.
- EFI method also provide us the opportunity to incorporate the prior knowledge on imaging domain in SD rank formulation.

Thank you

References

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- H. Dehghani, S. Srinivasan, B. W. Pogue, and A. Gibson, “Numerical modelling and image reconstruction in diffuse optical tomography Numerical modelling and image reconstruction,” 2009.