SAND2015-7125C

Photos placed in horizontal position with even amount of white space between photos and header

Big-Data X-ray Phase Contrast Imaging System Simulation Challenges

Edward S. Jimenez and Amber Dagel

Sandia National Laboratories

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Introduction

- Is it possible to create a big-data X-ray Phase Contrast Simulator?
  - Fine resolution
  - Wide field-of-view
  - Bremsstrahlung Radiation

- Specifically, a Talbot-Lau XPCI System
  - Three gratings and an object of interest
  - Source-to-Detector on the order of meters
  - 2x2 inch detector with 2048x2048 pixels

Continued

- Why BDXPCI?
  - Predict and corroborate experimental results
  - Quantify influence of imperfections and variation of system
  - Forward-projector for iterative CT reconstruction algorithms

- Challenges
  - Computationally daunting
  - Numerical stability/accuracy
  - Big-data/Information movement across architecture

Background

- A brief literature survey yielded no Talbot-Lau simulations

- Four efforts will be briefly discussed
  - Peterzol et. Al.
  - Wolf et. Al.
  - Cipiccia et. Al.
  - Peter et. Al.

- Although these efforts are not ideal fits for our objective, they help identify challenges in BDXPCI.

Peterzol et. Al.

- Robust and deterministic implementation
  - Large FOV
  - Grating-free XPCI
- CAD Model object representation
  - Efficient
  - Large objects
  - NURBS
- Challenges
  - CAD limits representable objects
  - Can gratings be treated as objects?

Wolf et. Al.

- Fast XPCI
  - Parallelizable
  - Restructure computation from 2D plane wave to 1D lines.
- Acknowledges big-data problem
  - Only use information relative to give 1D line computation.
  - Full-scale representation example: >16TB
- Challenges
  - Will spherical waves add computational complexity?
  - Limited FOV
  - Although optimized, achieved 100 pixels processed per second.

Cipiccia et. Al. and Peter et. Al.

- Both propose Monte-Carlo methods
  - Talbot imaging represented
  - Good agreement with experimental data
- Approximately 10^9 particles are simulated.
  - Small FOV
  - Short propagation
- Challenges:
  - MC is very computationally expensive
  - Parallelization is challenging

Approach

- Try Talbot-Lau using Peterzol et. Al. inspired approach.
  - Most efficient approach identified
- Represent each grating and object of interest as a distinct object.
  - Is CAD sufficient.
  - Voxelized representation may be needed
- Very fine sampling is needed
  - Over large FOV, big data problem
  - Interpolation stability
- Propagation will require convolution
  - FFT essentially required.
  - FFT stability on large arrays/vectors is a problem.

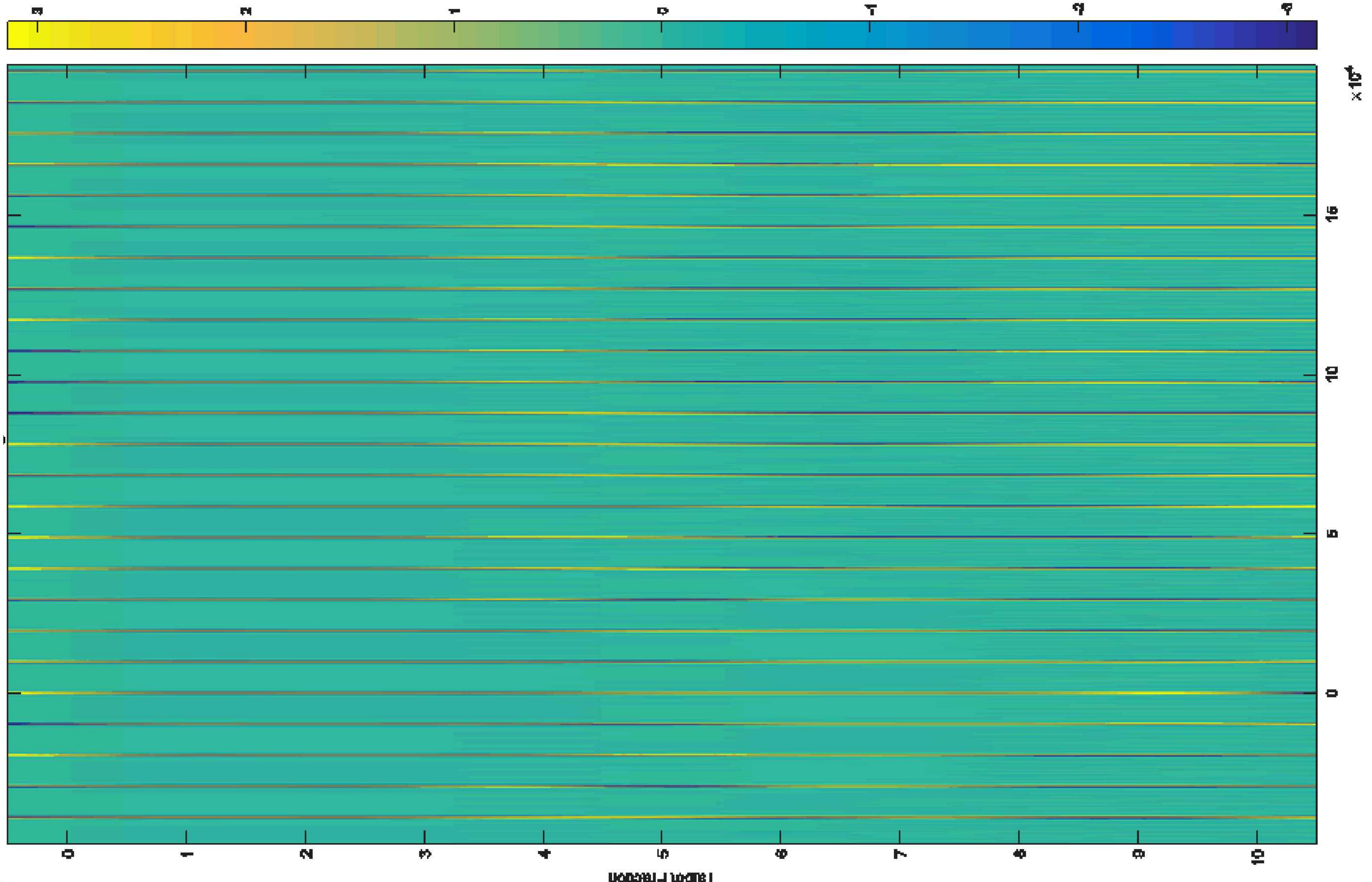
Talbot Images

- To illustrate difficulty of Talbot imaging on big data, two demos will be presented

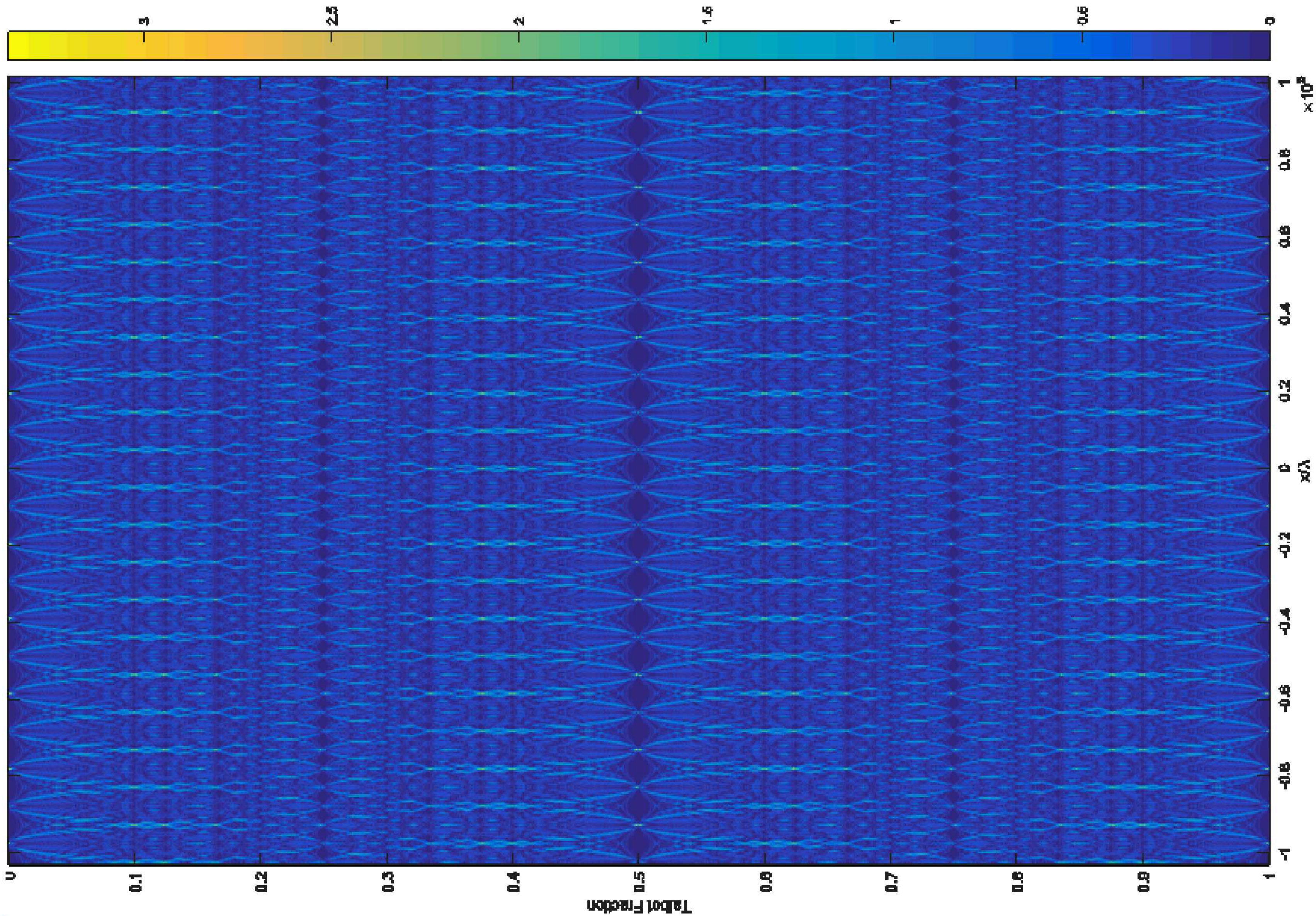
- Demo 1:
  - 1D Plane wave Talbot images propagated over 10 Talbot distances
    - 2^{13} sampled points
    - 3/40 aperture ratio
  - FFT numerical stability

- Demo 2:
  - Compare 2 Talbot images where input differs by 10^{-16}
  - Influence of error in object sampling.

Demo 1



Demo 2



Conclusions

- Although challenges exist, BDXPCI may be feasible.
  - Algorithm Design
- Graphics processors may help
  - Not without challenges.
- Industrial NDT/NDE R&D will benefit
  - System characterization
  - Polychromatic Radiation
  - Reconstruction algorithms.