IOCC 2026 Conference
The 5th International Online Conference on Crystals
15–17 June 2026 | Online
MDPI

Investigation of detector technology alternatives in Cone beam CT: A Simulation study

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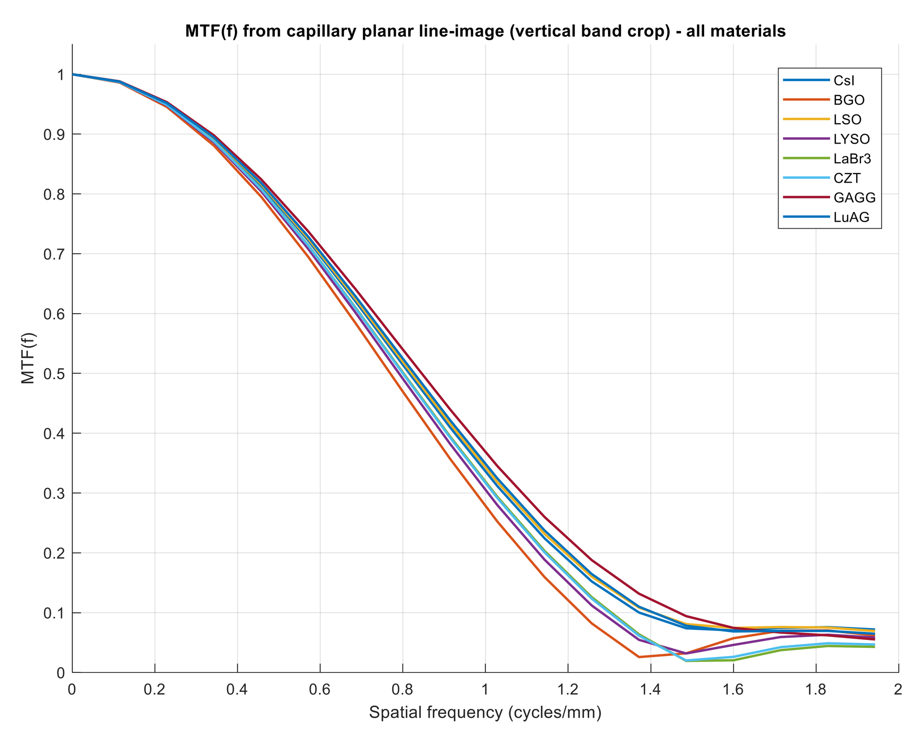
INTRODUCTION & AIM

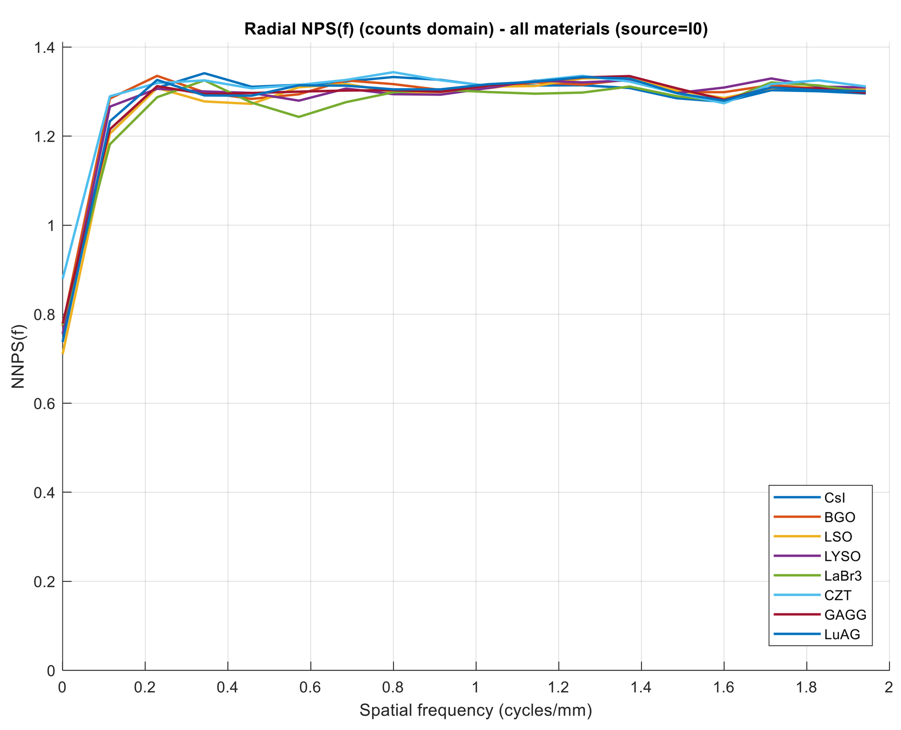
- Cone beam CT (CBCT) is an excellent alternative in breast imaging since the breast is uncompressed while CBCT image quality is adequate, even in dense breast.
- CBCT detector technology is based on CsI:Tl material but recent research explores photon counting detectors' technology adapted from nuclear medicine.
- A key question is whether an optimum detector configuration exists in terms of MTF (Modulation transfer function), which reflects spatial resolution, and DQE (Detective quantum efficiency), reflecting the overall image quality.
- Image quality can also be defined from CNRs (Contrast to noise Ratios) of a dense phantom containing microcalcifications of Type I like $CaCO_3$ (calcium carbonate) and Type II like HAp (hydroxyapatite). Type II indicates malignancy.

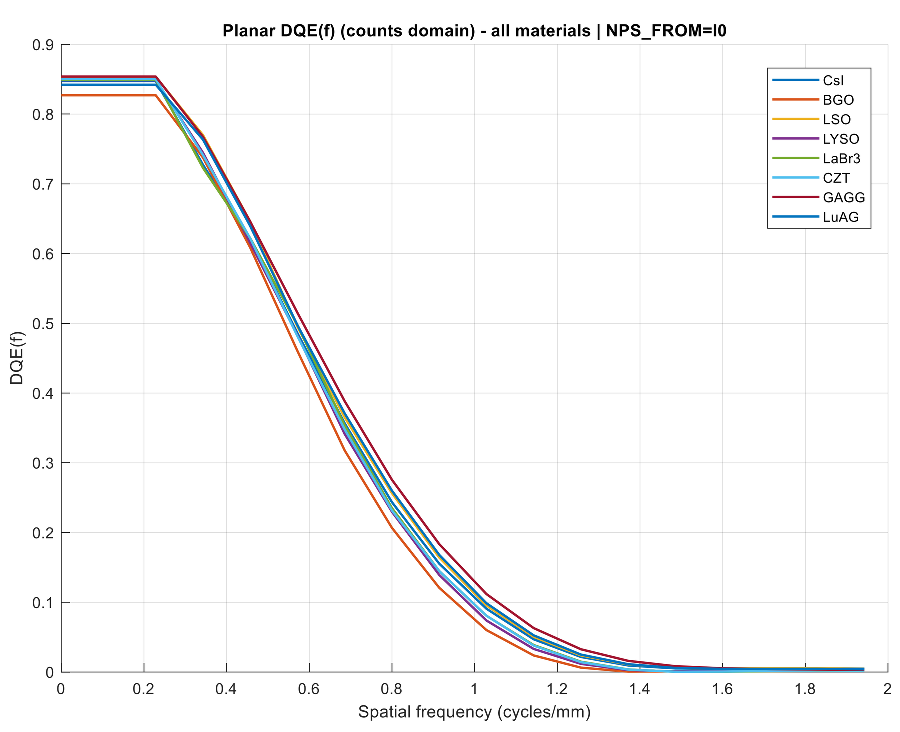
METHOD

- A micro-CBCT system was simulated in GATE (GEANT4 Application for Tomographic Emission) v.9.2 incorporating seven different detector configurations.
- The scintillators evaluated were BGO (light yield: 8000-10000 photons/MeV), LSO (25000-30000 photons/MeV), LYSO (30000-38000 photons/MeV), $LaBr_3$ (60000-70000 photons/MeV), GAGG (40000-60000 photons/MeV) and LuAG (18000-25000 photons/MeV) along with CZT as a semiconductor.
- These materials were selected due to their higher density and effective atomic number (Zeff) compared to CsI, which can enhance DQE.
- Each scintillator (50x50x1 mm^3) was discretized in 100x100 pixels and coupled to a generic SiPM (Silicon photomultiplier) with pixelated readout.
- A 40 keV X-ray spectrum was used.
- A 1mm aluminum capillary and a cylindrical water phantom (20 mm height and 16 mm diameter) were simulated, along with a dense breast phantom containing HAp and $CaCO_3$ microcalcifications.
- CNR values were extracted from the dense breast phantom.

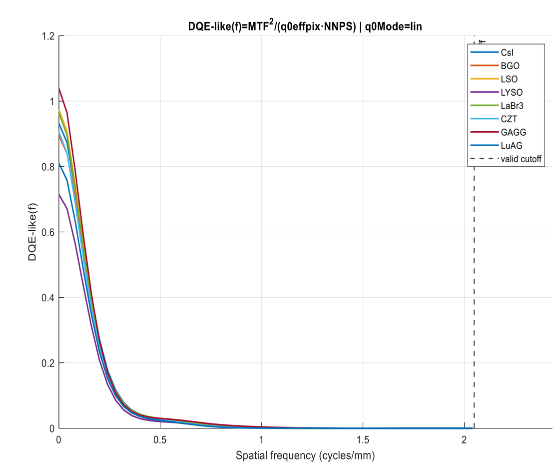
RESULTS & DISCUSSION

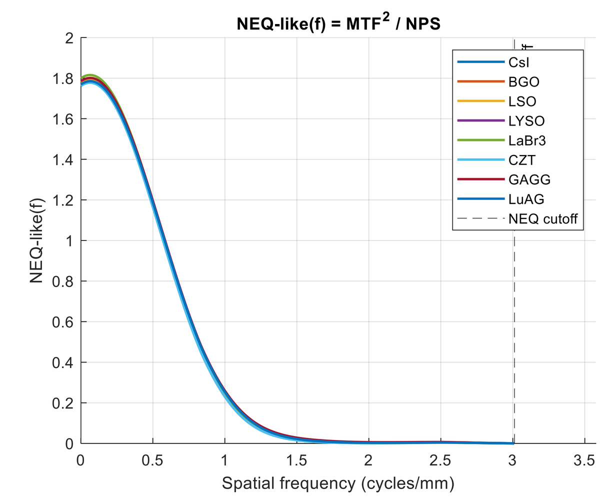




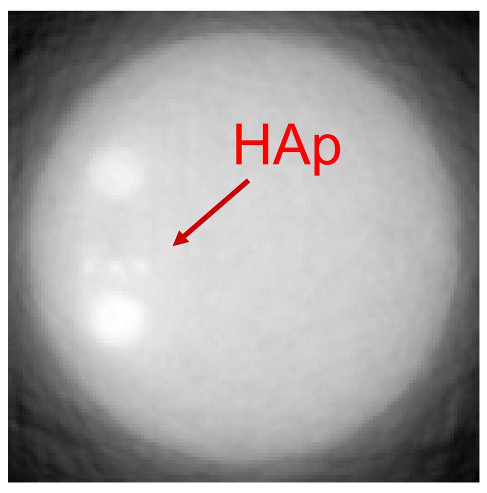


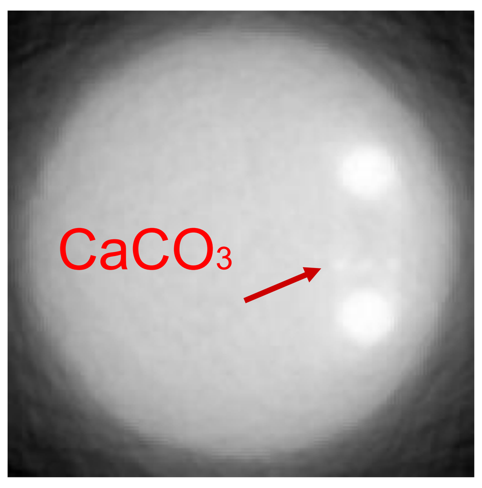
Planar mode MTF, radial NPS, and DQE curves.





Tomographic mode FBP DQE-like and OS-SIRT NEQ curves.





Material	mean CNR HAp	mean CNR $CaCO_3$
CsI	5.1462	3.8704
BGO	4.9279	3.8462
LSO	5.0888	3.7074
LYSO	4.9606	3.8216
$LaBr_3$	4.8536	3.8177
CZT	5.1155	3.8448
GAGG	5.3288	3.9776
LuAG	5.1379	3.7553

Mean CNR from slice #25 and slice #75 of a dense breast phantom containing HAp and $CaCO_3$ microcalcifications.

- GAGG demonstrated a 4% increase in spatial resolution and an 11% increase in DQE compared to CsI.
- Similar results were obtained from FBP (Filtered backprojection algorithm) and OS-SIRT (Ordered subsets simultaneous iterative reconstruction technique) reconstructed images.
- GAGG's high light yield (40000-60000 photons/MeV), high density (6.6-6.7 g/cm^3) and high Zeff, contribute to improved signal to noise ratio (SNR).
- Additionally, it offers fast decay time (80-100 ns) and a low afterglow, good energy resolution, and robust mechanical properties.

CONCLUSIONS

- GAGG is a strong candidate for CBCT detectors, offering improved spatial resolution, image quality and matched well in SiPM readout systems.
- In comparison to CZT is preferred in low dose applications and it is more cost-effective.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

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