Department of Physics
Microwave Laboratory

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Modulated Multimode Mixing Illumination for the Elimination of Speckle and Target Orientation Requirements in Active Imaging

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Attractions of Sub-millimeter wave Imaging

Higher resolution than low frequencies

and

More penetration than high frequencies

Attractions of Active Imaging

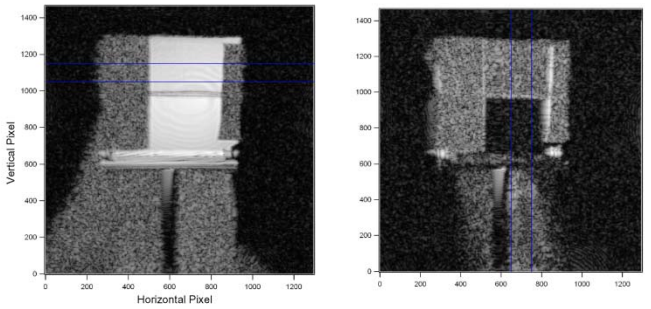
Very high source temperatures (>10^{14} K)

and/or

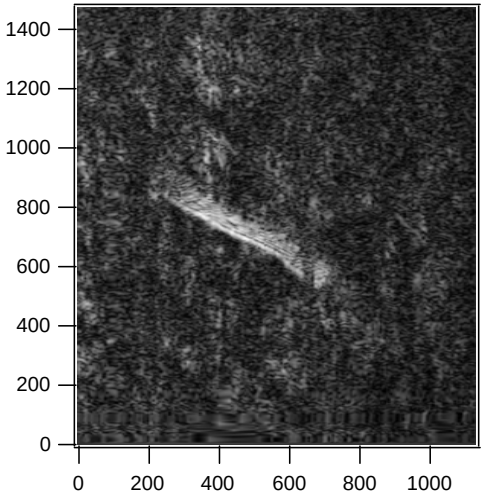
Avoids low thermal contrast of some passive scenes

Active Imaging Challenges

1. **Orientation of Specular Targets**



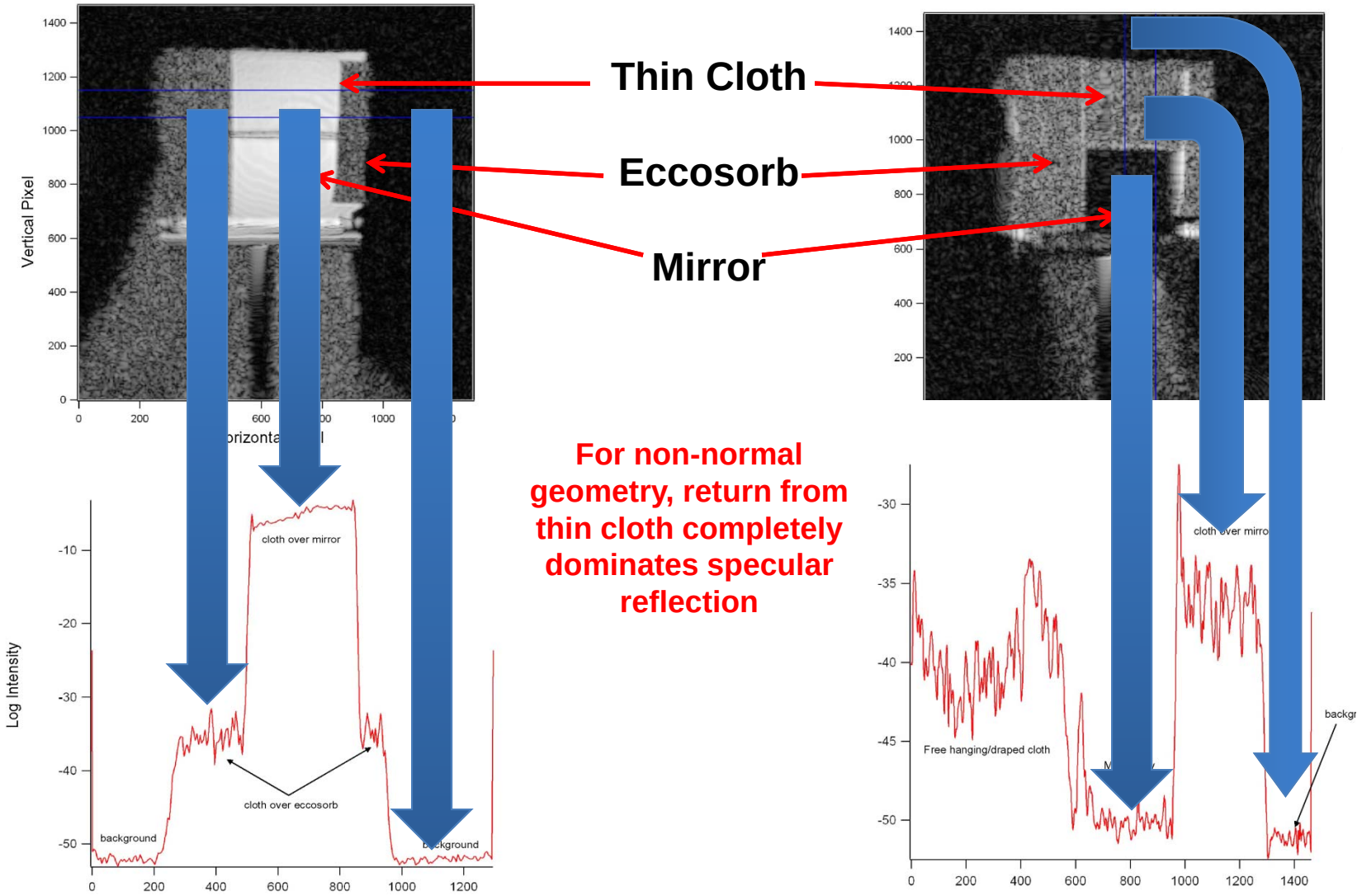
2. **Coherent Effects (Speckle) of Diffuse Targets**



1a. Need for Strategic Target Orientation

Normal (typical demonstration)

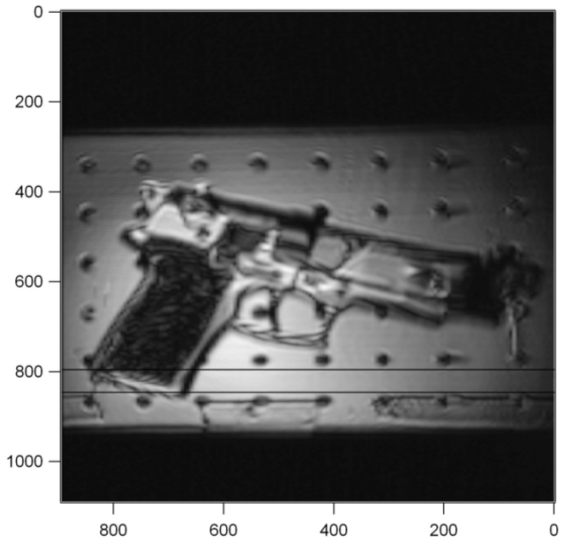
rotated (typical application)



For non-normal geometry, return from thin cloth completely dominates specular reflection

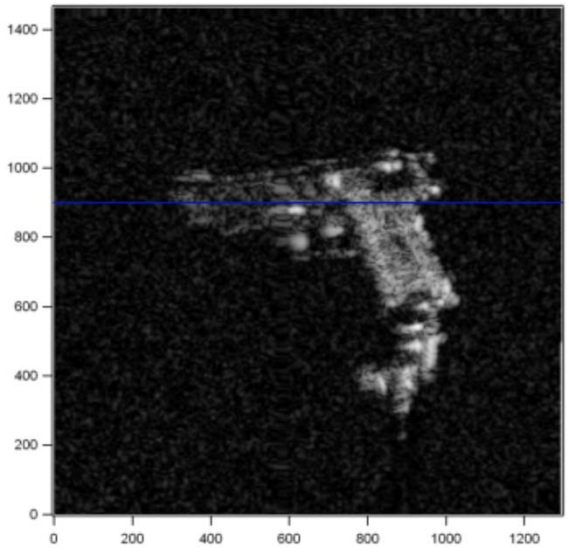
1b. Need for Strategic Target Orientation

Gun at normal incidence (linear image)

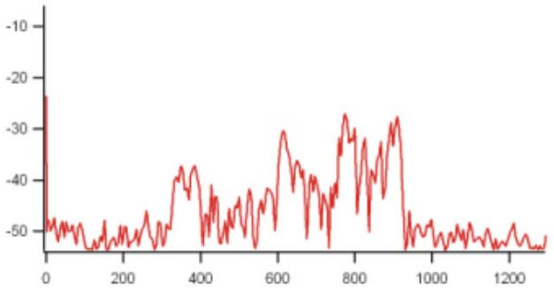


For reference, the signal from a gun at normal incidence is ~ -5 db

Gun rotated from normal (logarithmic image)



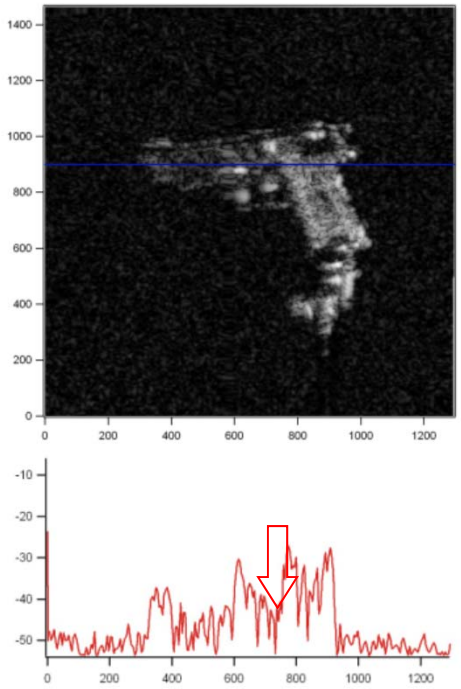
Down 20 - 40 db



2. Speckle Noise from Diffuse Targets

Dynamic Range in Real Targets in single mode active systems is large and this dynamic range include important signature information

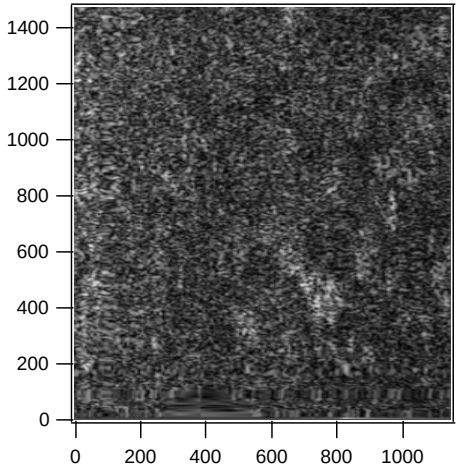
Gun rotated Uncovered



Much of image is down 20 - 40 db

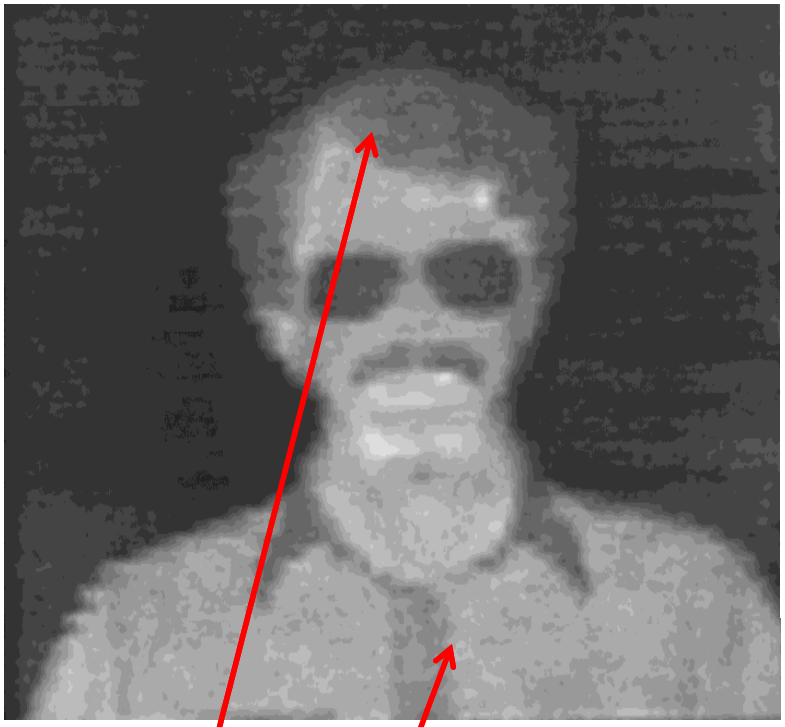
Coherent noise from covering obscuration > most returns from target in single mode system

Gun rotated under a heavy robe



1+2. Angle and Coherent Effects in Active Images

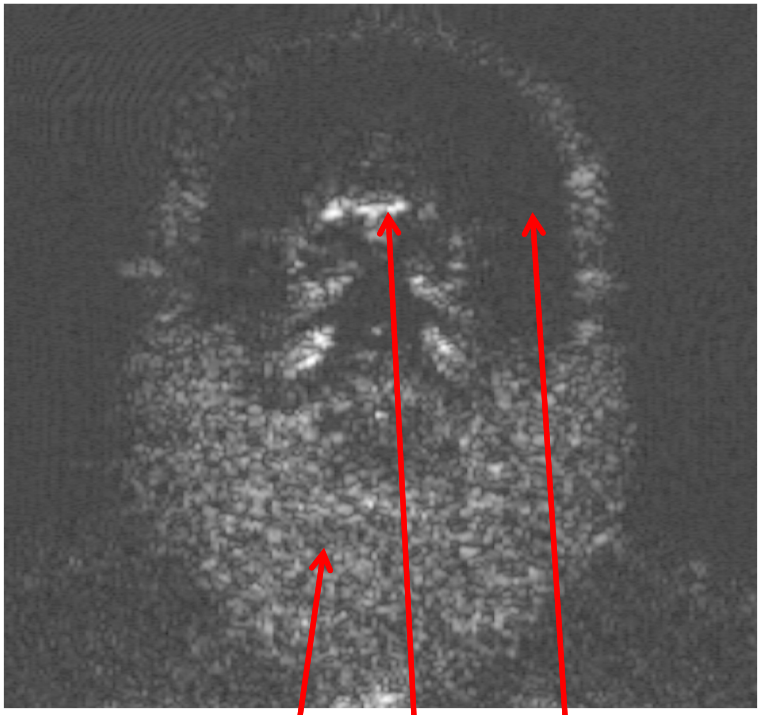
Passive Image



No Speckle

No orientation requirements

Active Image



Speckle

Normal orientation

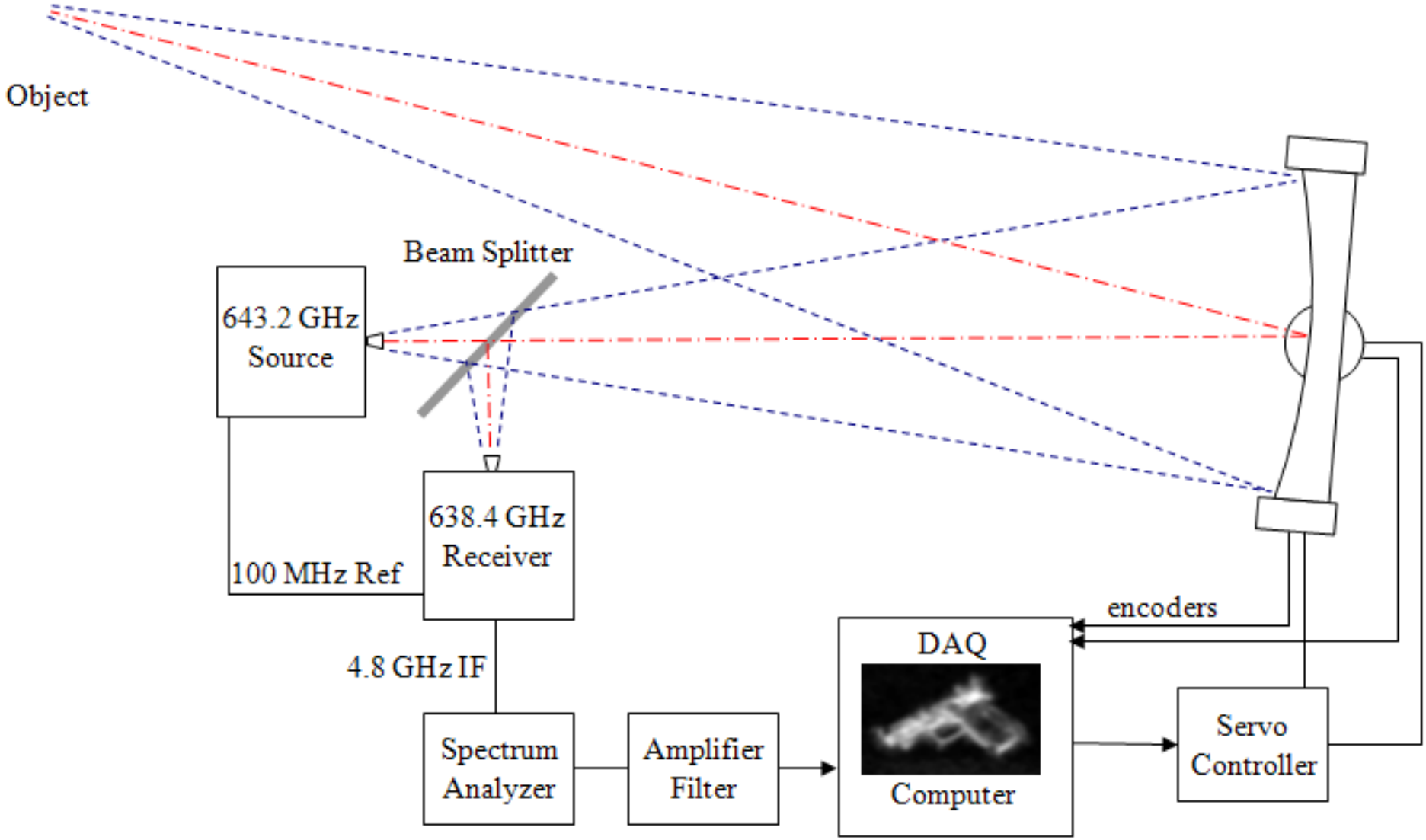
Non-normal orientation

Experimental Results

640 GHz system on size scale of 2 m with 1 mW power

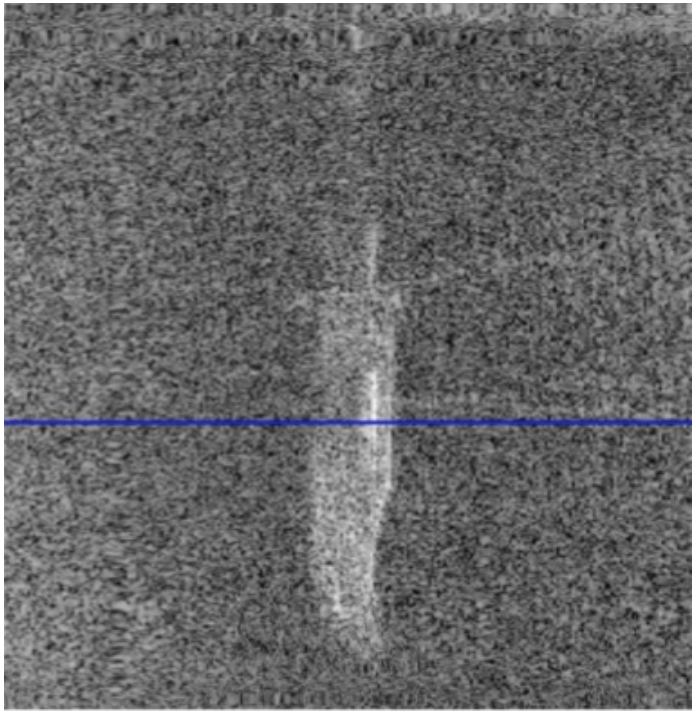
217 GHz system on size scale of 50 m with 5 W power

640 GHz Imager

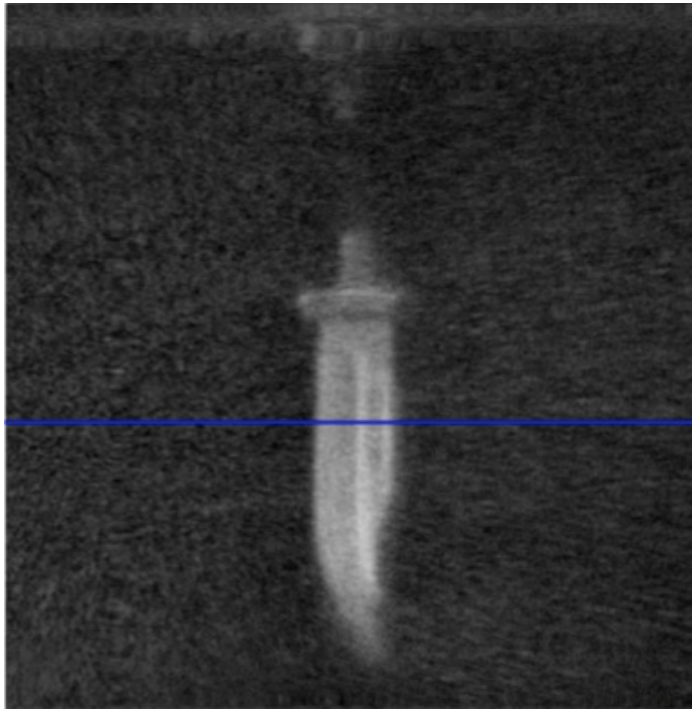


Angular Diversity in Illumination
(a kind of mode mixing)

Knife under medium weight robe



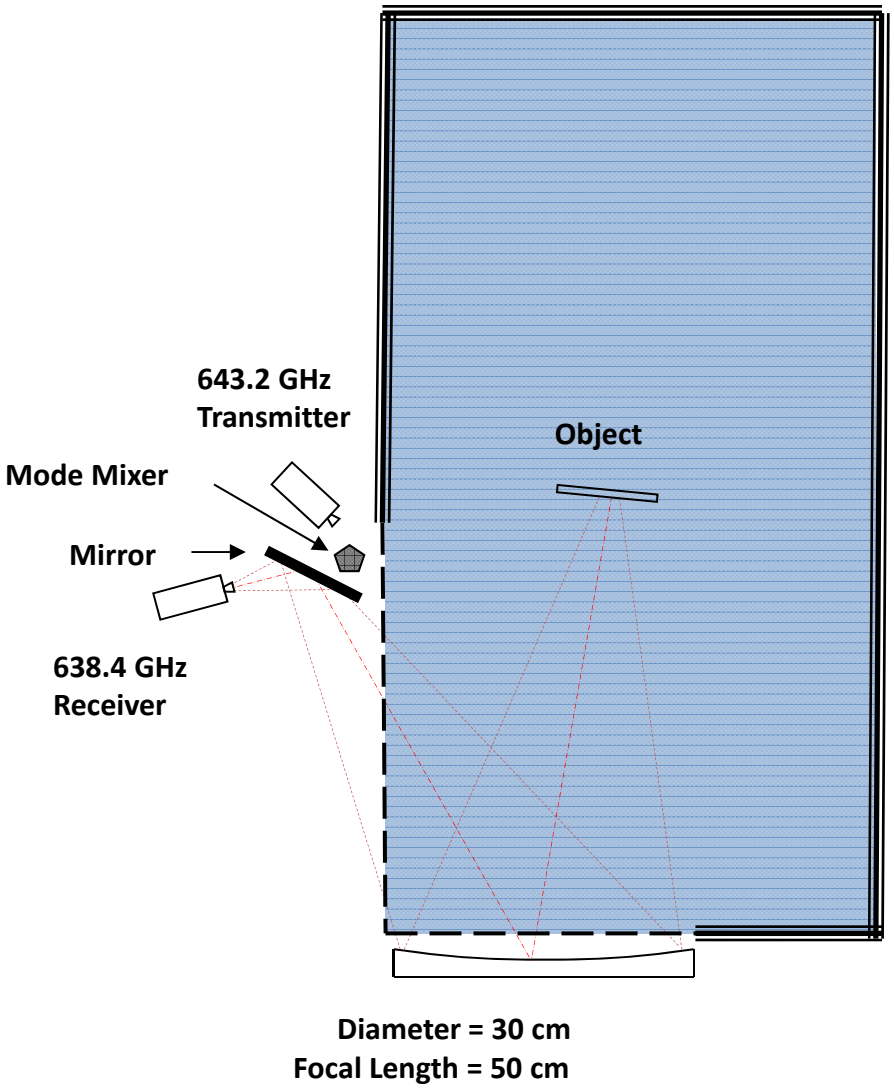
1 Angle



16 Angles

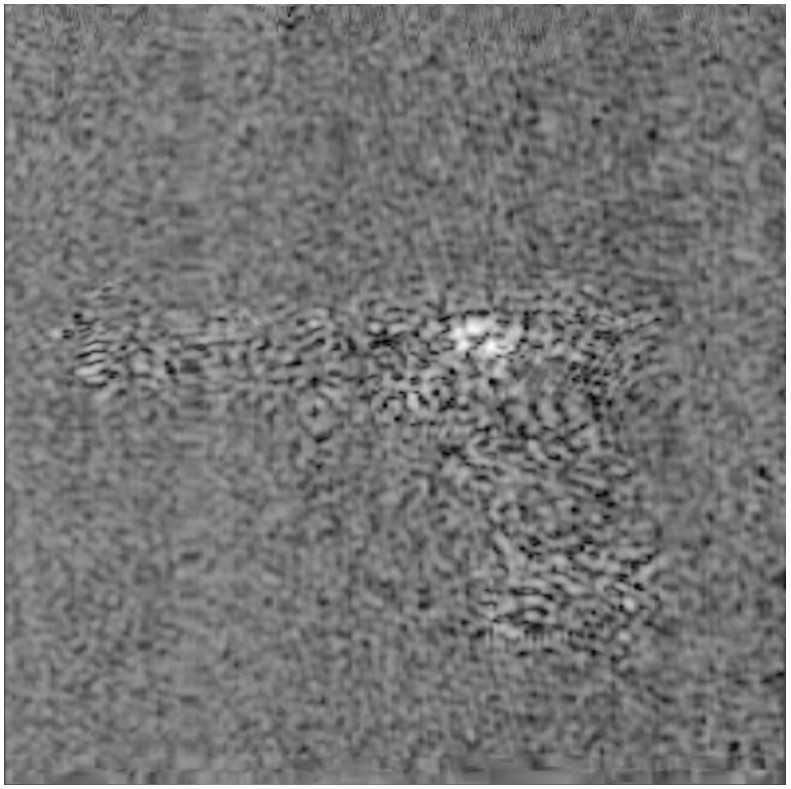
Speckle noise reduced by $16^{1/2}$ = 4 incoherent speckle average

Modulated Multimode Mixing

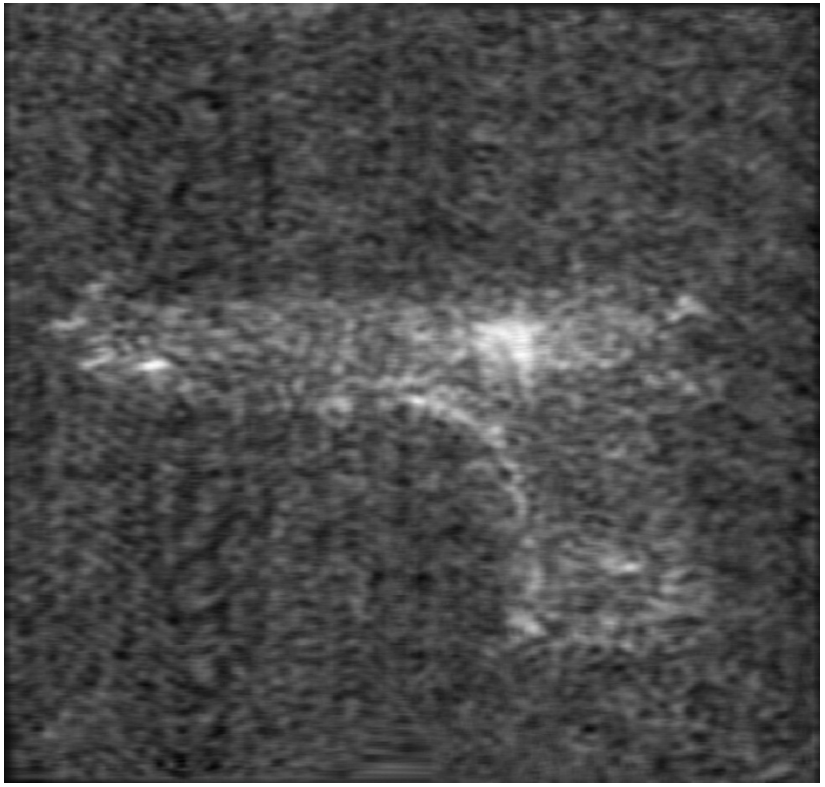


- **Illuminate object from many angles (coherent without mode mixing modulation)**
- **Mirror rotating much faster than pixel dwell time (incoherent with mode mixing modulation)**

Speckle Reduction



No mode modulation



Partial mode modulation

Modes and Angles: Active and Passive Imaging in the THz

1 mW in 1 MHz corresponds to a noise temperature of ~10^{14} K

A reasonable receiver noise temperature is 3000 K

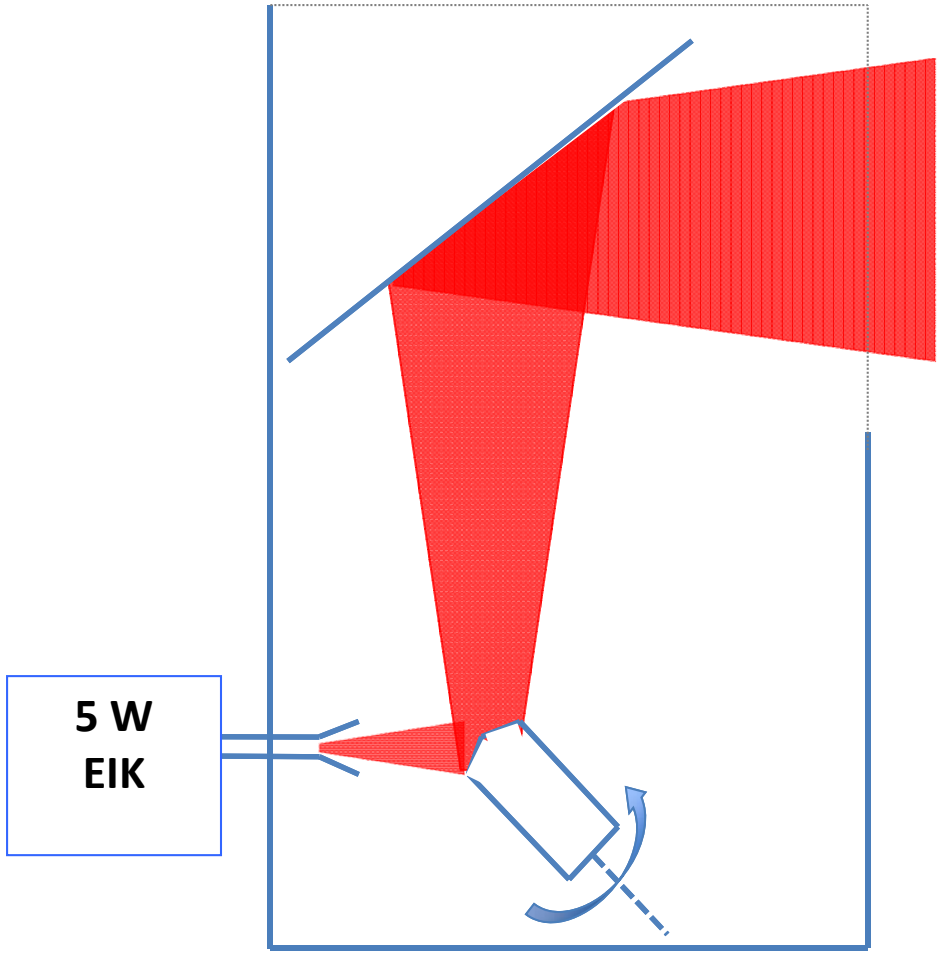
Floodlight limit: If an illuminator of power P_I is used to flood light (i.e. fill all modes) of an object whose scale is *l, in a 1 MHz bandwidth* the temperature/mode is

With *l* = *1* m, λ = 1 mm T_I ~ 10^8 K $$T_I = \left(\frac{P_I}{k\Delta\nu}\right)\left(\frac{\lambda}{l}\right)^2$$

Random illumination limit: A practical way to get spotlight illumination would be to illuminate the whole room or 'urban canyon' assume a 10% reflection, and let the target come into equilibrium with the room. If we let *l* = 100 m, then

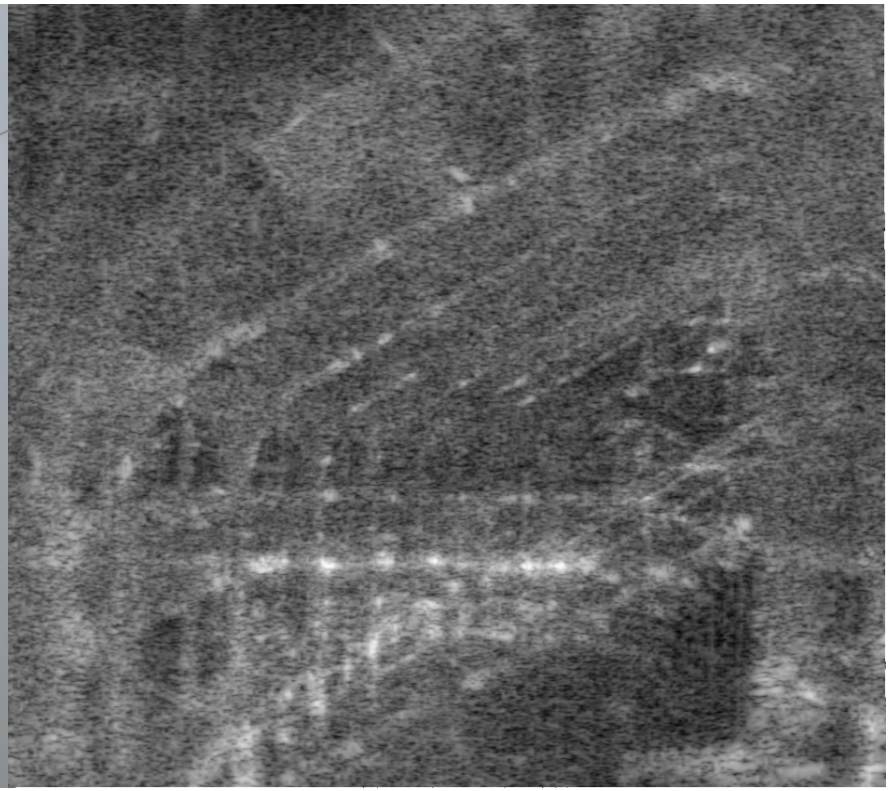
T_I ~7 x 10^2 *K*(1 mW) or T_I ~4 x 10^6 K (5 W) .

217 GHz Imager



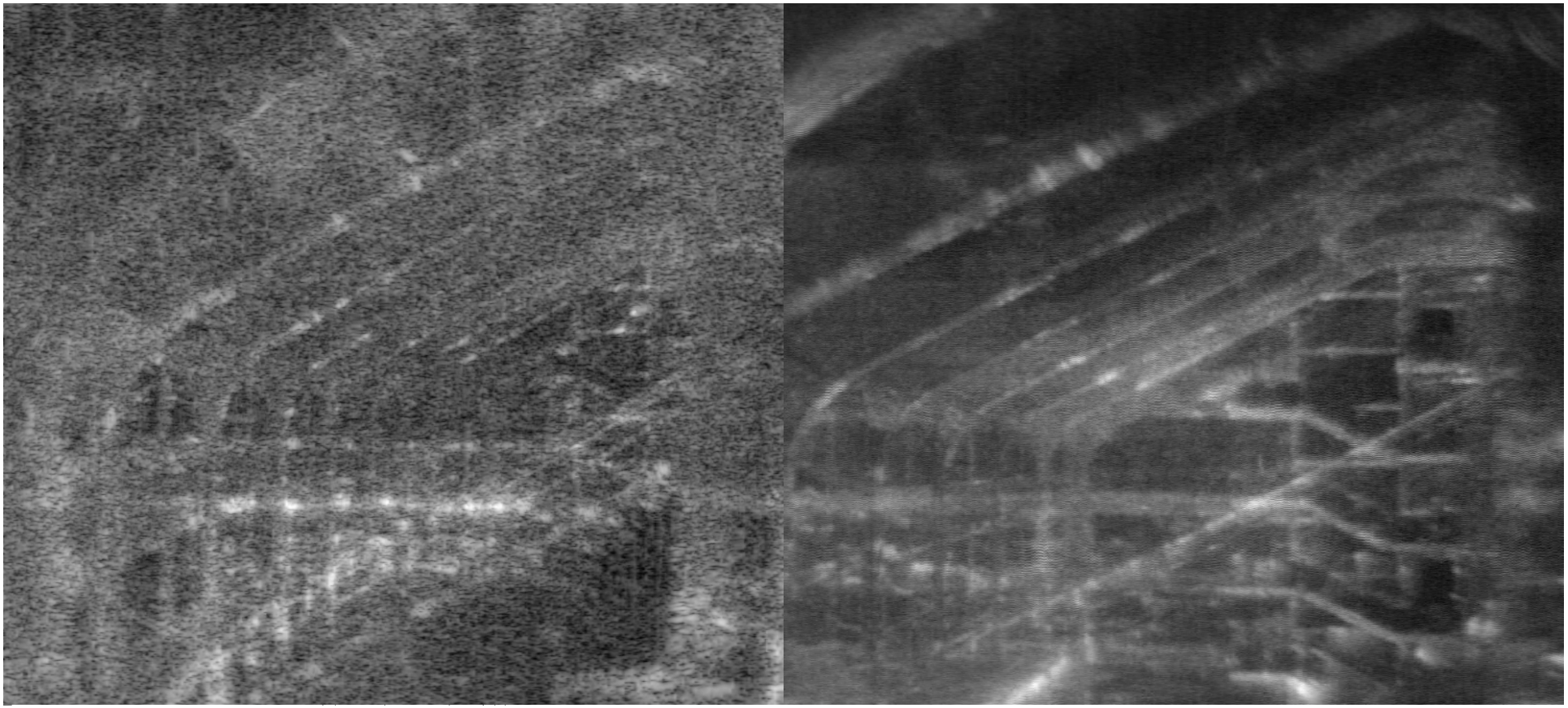
Physics Atrium as 50 Meter Range

Optical Image



217 GHz Image
(without mode modulation)
Speckle and specular dominance

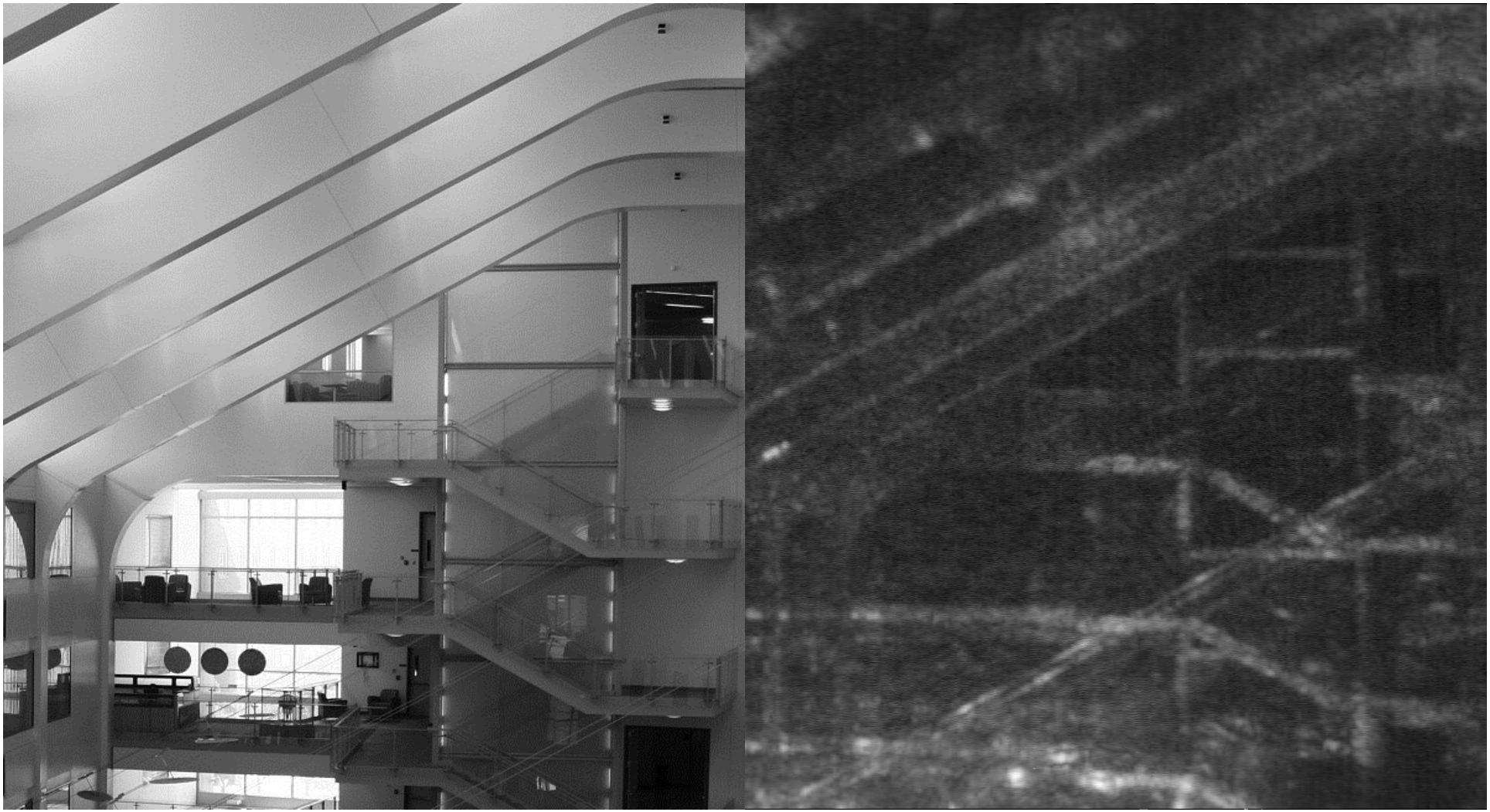
Modulated Multimode Mixing



217 GHz Image
(without mode modulation)

217 GHz Image
(with mode modulation)

Enlargement of Wall/Staircase at 50m



Conclusions

Modulated Mode Mixing has successfully eliminated both the need for special angles and coherent speckle in active imaging

The 5 W EIK has made this possible in a large volume, but with 5 W still far from range limit

Illumination and mode mixing strategies can be improved and optimized, especially for extension to greater range (e.g. urban canyons)

Objects of interest (e.g. wires) are readily observable