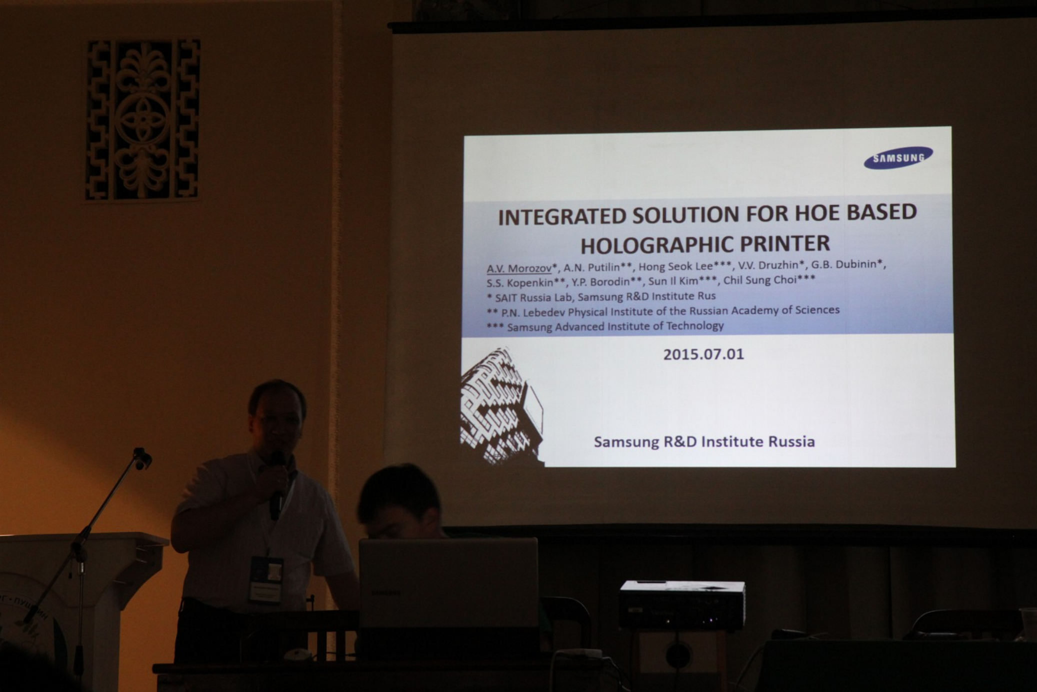
SAMSUNG
INTEGRATED SOLUTION FOR HOE BASED HOLOGRAPHIC PRINTER
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2015.07.01
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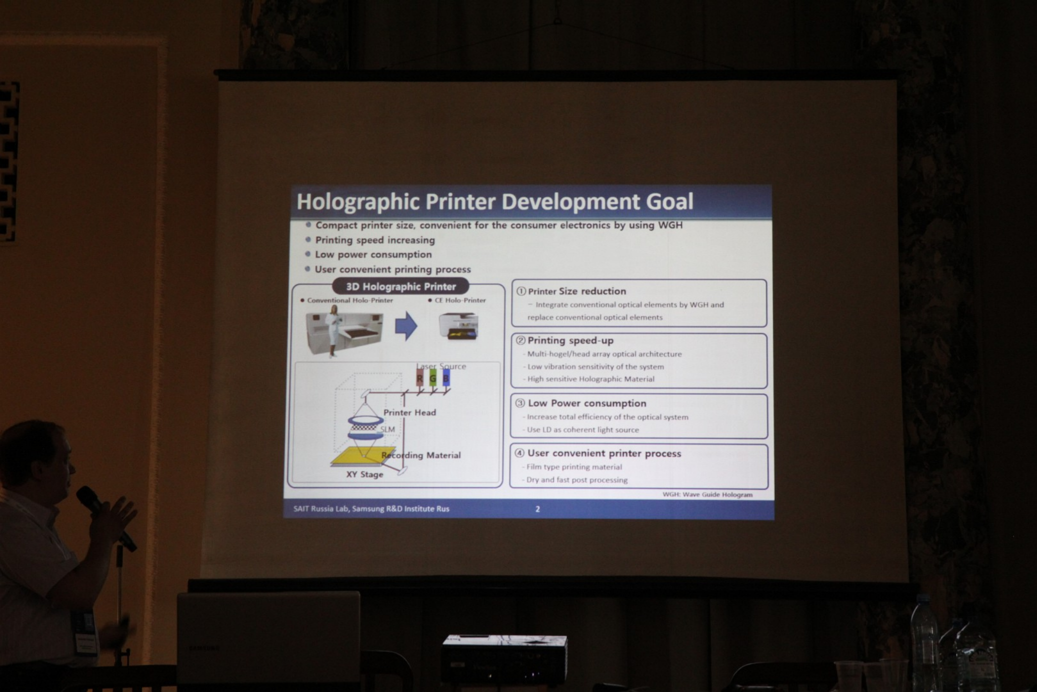

Holographic Printer Development Goal
Compact printer size, convenient for the consumer electronics by using WGH
Printing speed increasing
Low power consumption
User convenient printing process
3D Holographic Printer
Conventional Holo-Printer
CE Holo-Printer
Laser Source
R
G
B
Printer Head
SLM
Recording Material
XY Stage
① Printer Size reduction
– Integrate conventional optical elements by WGH and replace conventional optical elements
② Printing speed-up
- Multi-hogel/head array optical architecture
- Low vibration sensitivity of the system
- High sensitive Holographic Material
③ Low Power consumption
- Increase total efficiency of the optical system
- Use LD as coherent light source
④ User convenient printer process
- Film type printing material
- Dry and fast post processing
WGH: Wave Guide Hologram
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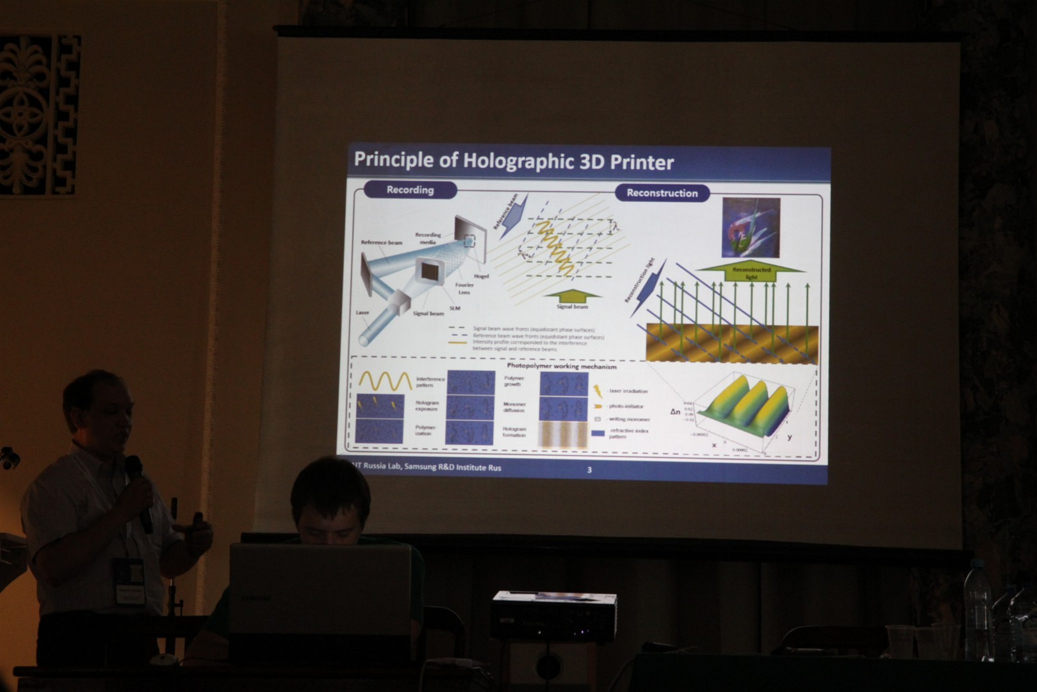
Principle of Holographic 3D Printer
Recording
Reconstruction
Reference beam
Recording media
Hogel
Fourier Lens
SLM
Signal beam
Laser
Reference beam
λ
Signal beam
Signal beam wave fronts (equidistant phase surfaces)
Reference beam wave fronts (equidistant phase surfaces)
Intensity profile corresponded to the interference between signal and reference beams
Reconstruction light
Reconstructed light
Photopolymer working mechanism
Interference pattern
Hologram exposure
Polymer-ization
Polymer growth
Monomer diffusion
Hologram formation
- laser irradiation
- photo-initiator
- writing monomer
-refractive index pattern
Δn
x
y
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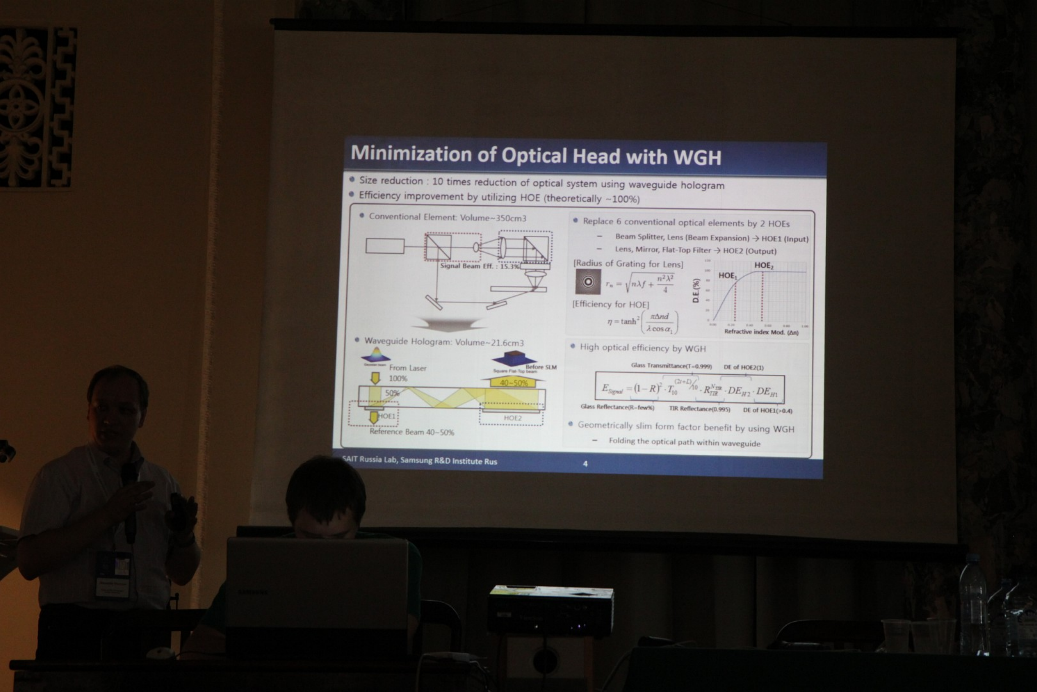

Minimization of Optical Head with WGH
Size reduction : 10 times reduction of optical system using waveguide hologram
Efficiency improvement by utilizing HOE (theoretically ~100%)
Conventional Element: Volume~350cm3
Signal Beam Eff. : 15.3%
Waveguide Hologram: Volume~21.6cm3
From Laser
100%
Before SLM
40~50%
50%
HOE1
HOE2
Reference Beam 40~50%
Replace 6 conventional optical elements by 2 HOEs
– Beam Splitter, Lens (Beam Expansion) → HOE1 (Input)
– Lens, Mirror, Flat-Top Filter → HOE2 (Output)
[Radius of Grating for Lens]
$r_n = \sqrt{n\lambda f + \frac{n^2\lambda^2}{4}}$
[Efficiency for HOE]
$\eta = \tanh^2\left(\frac{\pi\Delta n d}{\lambda\cos\alpha_1}\right)$
HOE1
HOE2
D.E.(%)
Refractive index Mod. (Δn)
High optical efficiency by WGH
Glass Transmittance(T=0.999)
DE of HOE2(1)
Glass Reflectance(R~few%)
TIR Reflectance(0.995)
DE of HOE1(>0.4)
Geometrically slim form factor benefit by using WGH
– Folding the optical path within waveguide
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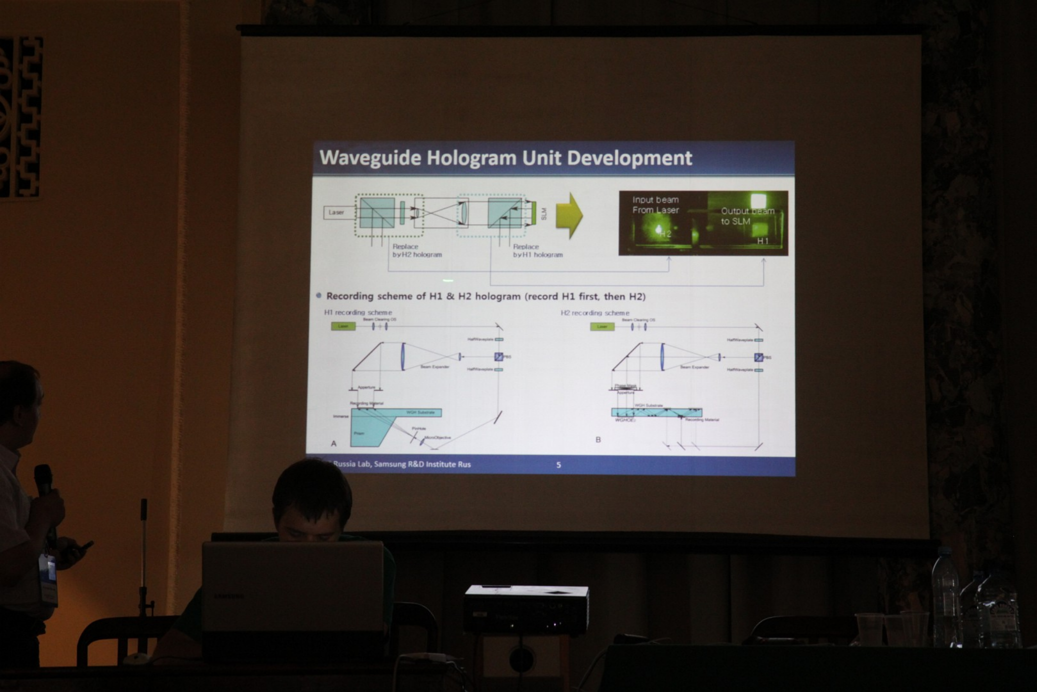

Waveguide Hologram Unit Development
Laser
SLM
Replace by H2 hologram
Replace by H1 hologram
Input beam From Laser
Output beam to SLM
H2
H1
Recording scheme of H1 & H2 hologram (record H1 first, then H2)
H1 recording scheme
H2 recording scheme
Beam Clearing OS
Laser
HalfWaveplate
PBS
Beam Expander
Apperture
Recording Material
WGH Substrate
Immerse
Prism
PinHole
MicroObjective
A
Phase Mask
WGHOE
B
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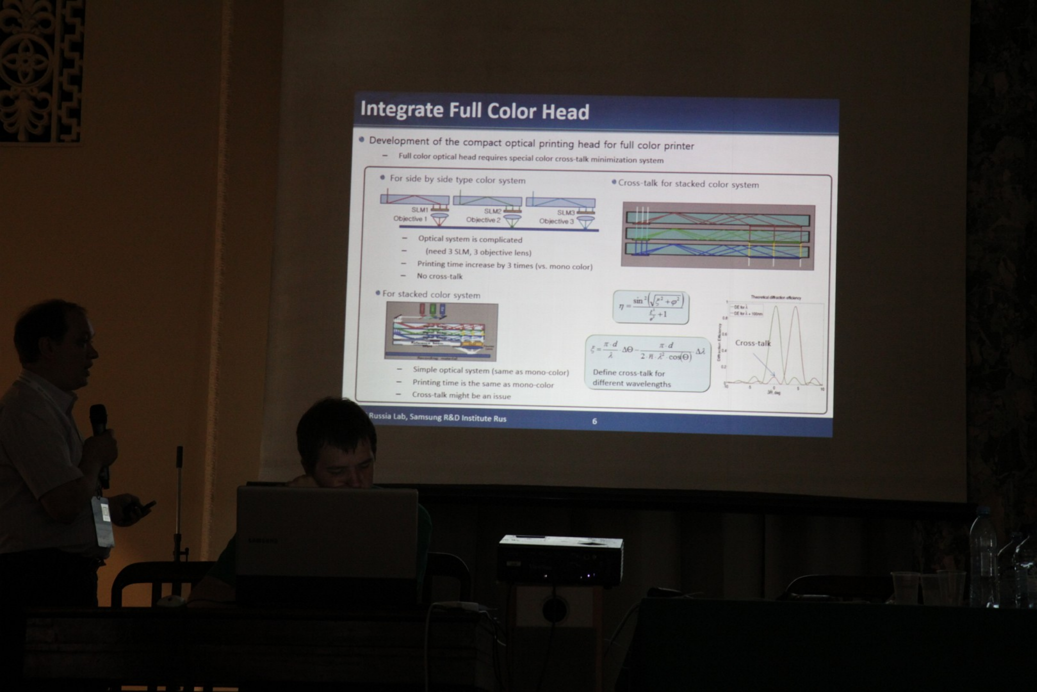

Integrate Full Color Head
Development of the compact optical printing head for full color printer
– Full color optical head requires special color cross-talk minimization system
For side by side type color system
SLM1
Objective 1
SLM2
Objective 2
SLM3
Objective 3
– Optical system is complicated
– (need 3 SLM, 3 objective lens)
– Printing time increase by 3 times (vs. mono color)
– No cross-talk
For stacked color system
– Simple optical system (same as mono-color)
– Printing time is the same as mono-color
– Cross-talk might be an issue
Cross-talk for stacked color system
$\eta = \frac{\sin^2\left(\sqrt{\xi^2+\varphi^2}\right)}{\frac{\xi^2}{\varphi^2}+1}$
$\xi = \frac{\pi \cdot d}{\lambda} \cdot \Delta\Theta - \frac{\pi \cdot d}{2 \cdot n \cdot \lambda^2 \cdot \cos(\Theta)} \cdot \Delta\lambda$
Define cross-talk for different wavelengths
Theoretical diffraction efficiency
Cross-talk
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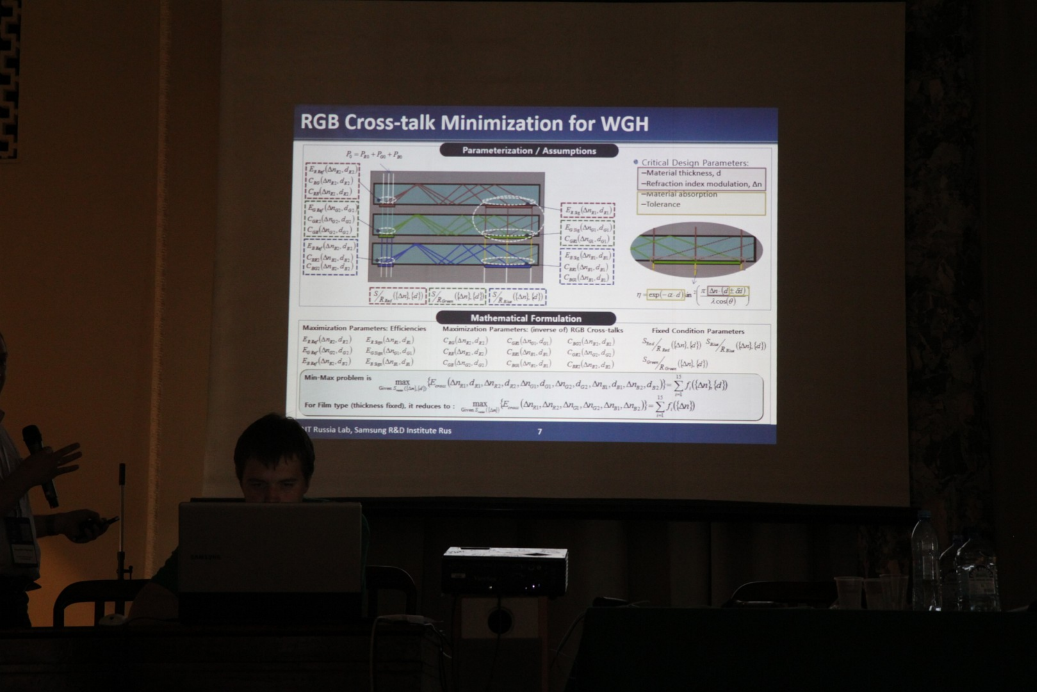

RGB Cross-talk Minimization for WGH
Parameterization / Assumptions
Critical Design Parameters:
–Material thickness, d
–Refraction index modulation, Δn
–Material absorption
–Tolerance
Mathematical Formulation
Maximization Parameters: Efficiencies
Maximization Parameters: (inverse of) RGB Cross-talks
Fixed Condition Parameters
Min-Max problem is
For Film type (thickness fixed), it reduces to :
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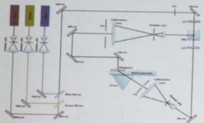
RGB WGH Experimental Results

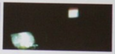
Recording Scheme



Samples

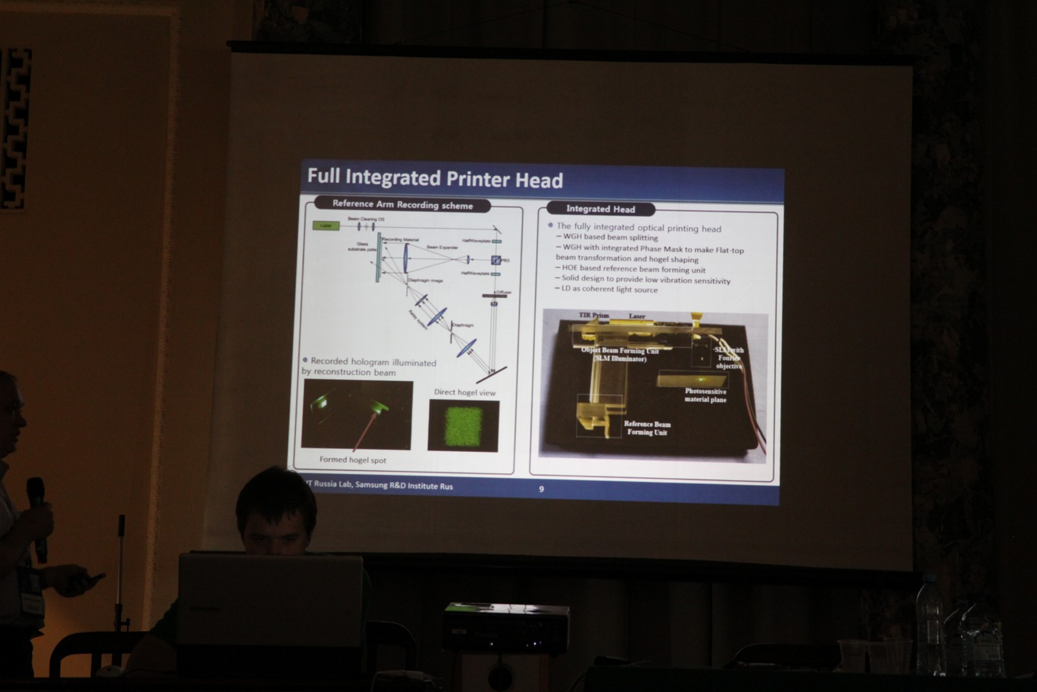
- Recorded WGHs

- Stacked RGB WGHs



- Crosstalk test results

		w/o beam shaping	With beam shaping
Red	on Green	1%<	1%<
	on Blue	1%<	1%<
Green	on Red	1%<	1%<
	on Blue	1%<	1%<
Blue	on Red	1%<	1%<
	on Green	1%<	1%<


Full Integrated Printer Head
Reference Arm Recording scheme
Laser
Beam Clearing OS
Recording Material
Beam Expander
HalfWaveplate
PBS
HalfWaveplate
Diaphragm image
Diffuser
Diaphragm
Recorded hologram illuminated by reconstruction beam
Direct hogel view
Formed hogel spot
Integrated Head
The fully integrated optical printing head
– WGH based beam splitting
– WGH with integrated Phase Mask to make Flat-top beam transformation and hogel shaping
– HOE based reference beam forming unit
– Solid design to provide low vibration sensitivity
– LD as coherent light source
TIR Prism
Laser
Object Beam Forming Unit (SLM Illuminator)
SLM with
objective
Photosensitive material plane
Reference Beam Forming Unit
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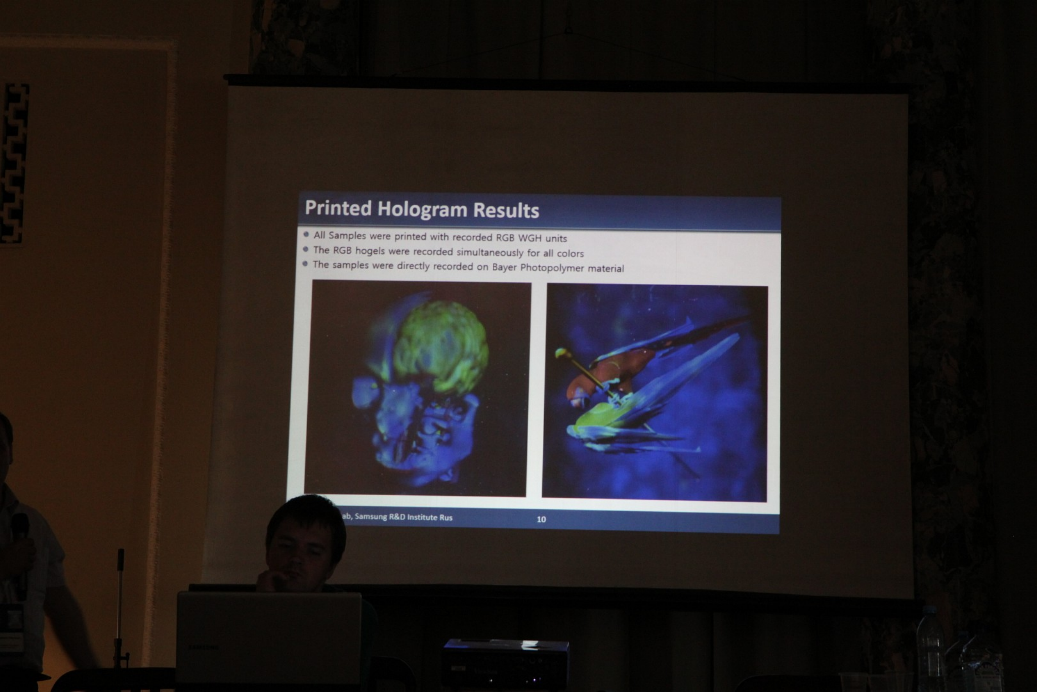
Printed Hologram Results
All Samples were printed with recorded RGB WGH units
The RGB hogels were recorded simultaneously for all colors
The samples were directly recorded on Bayer Photopolymer material
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