Rechargeable batteries: a combinatorial perspective

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Rechargeable batteries

- Battery components, characterization
  - Issues affecting Li-ion performance
- Combinatorial electrochemical methods:
  - Powder electrodes
  - Thin film electrodes, cells
  - Details of electrochemical apparatus
- Extension to hydrogen storage

Rechargeable battery performance

capacity

repeatability

rate

safety

Rechargeable battery performance

capacity

composition

repeatability

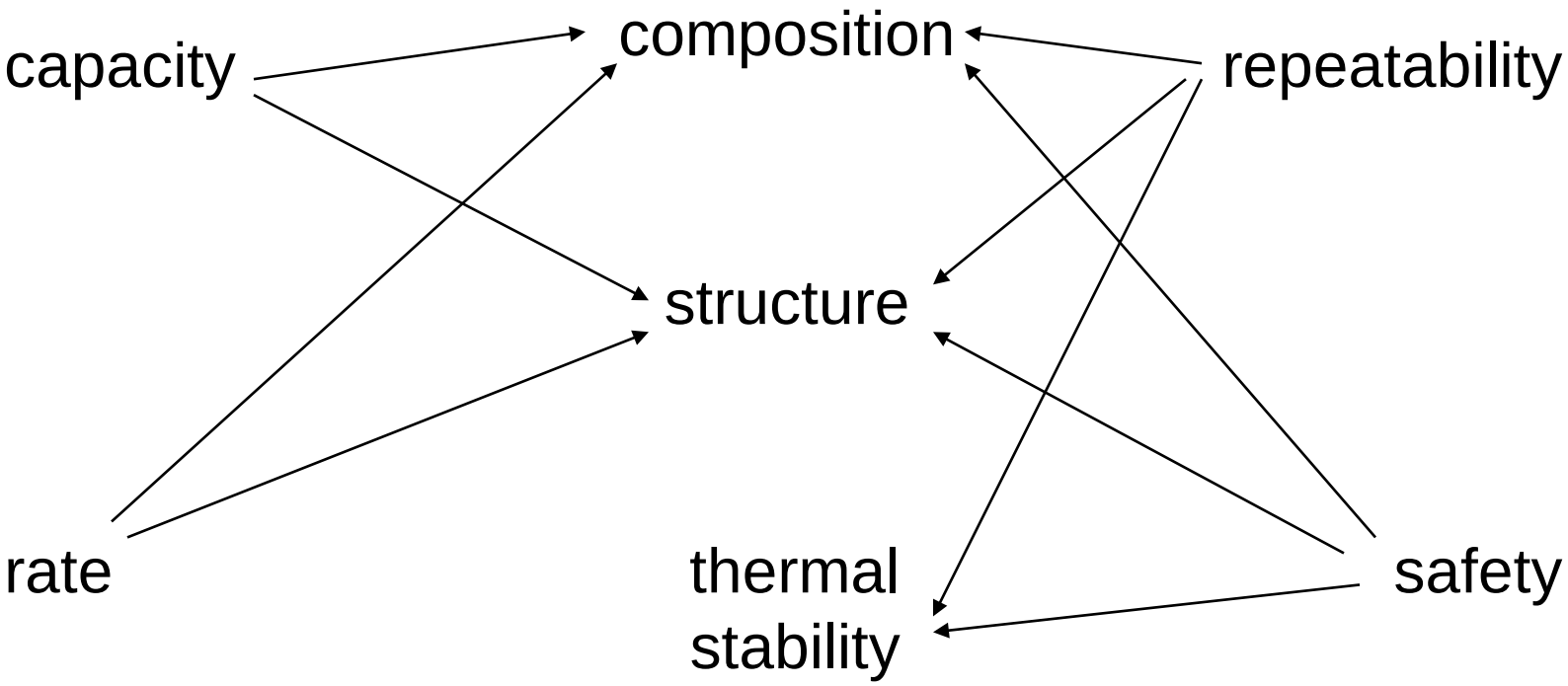
structure

rate

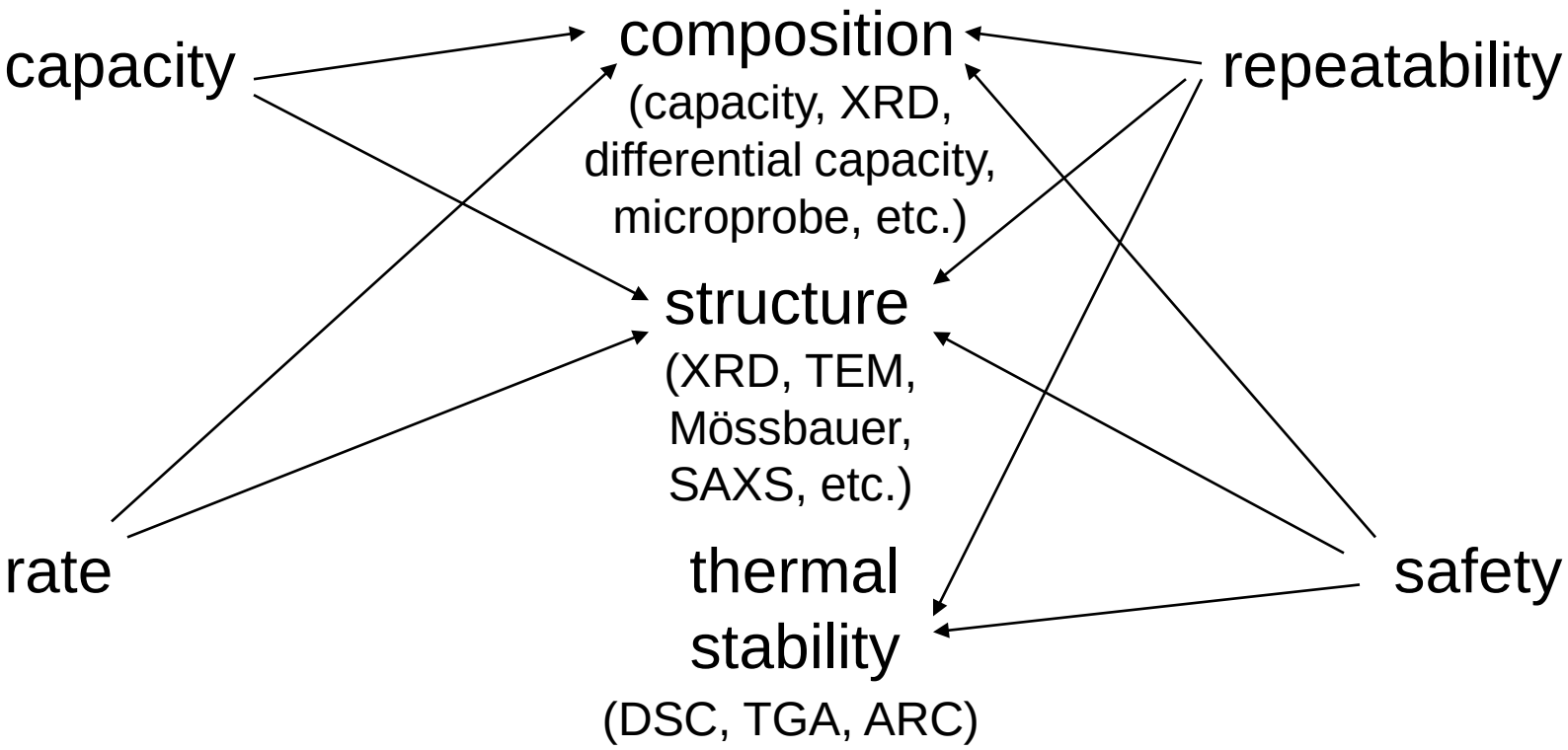
thermal stability

safety

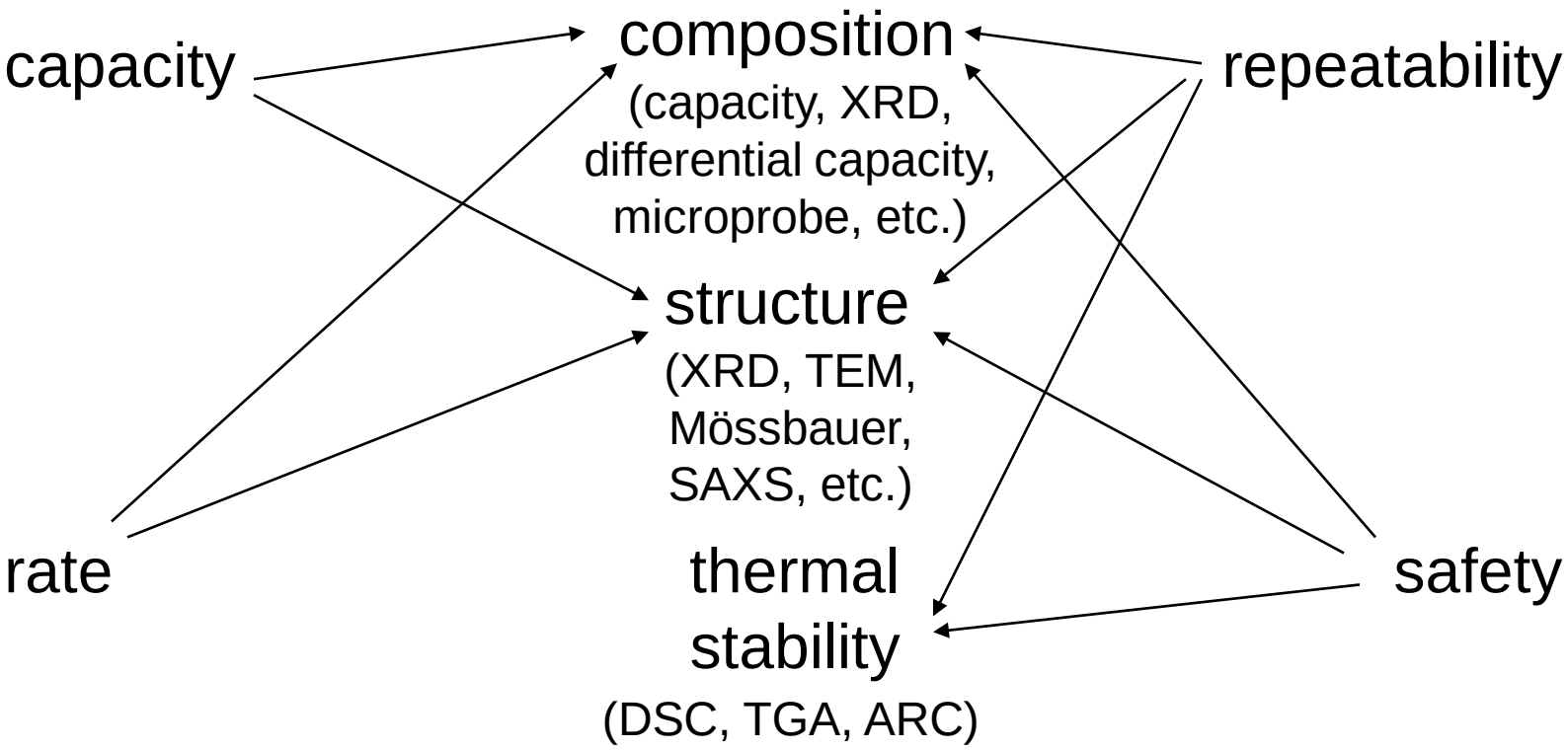
Rechargeable battery performance



Rechargeable battery performance

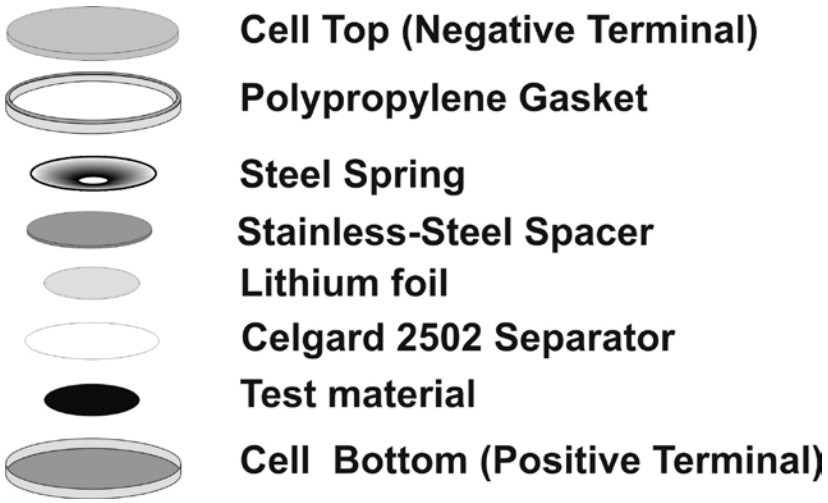


Rechargeable battery performance

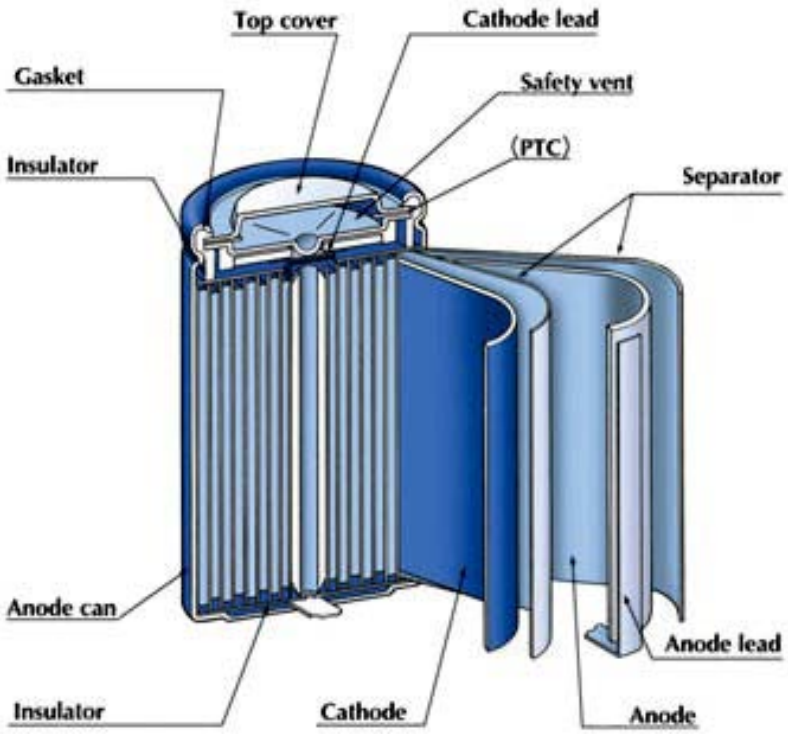


The challenge in combi battery is combi electrochemistry, the challenge with combi electrochemistry is sample preparation and cycling hardware.

Rechargeable batteries



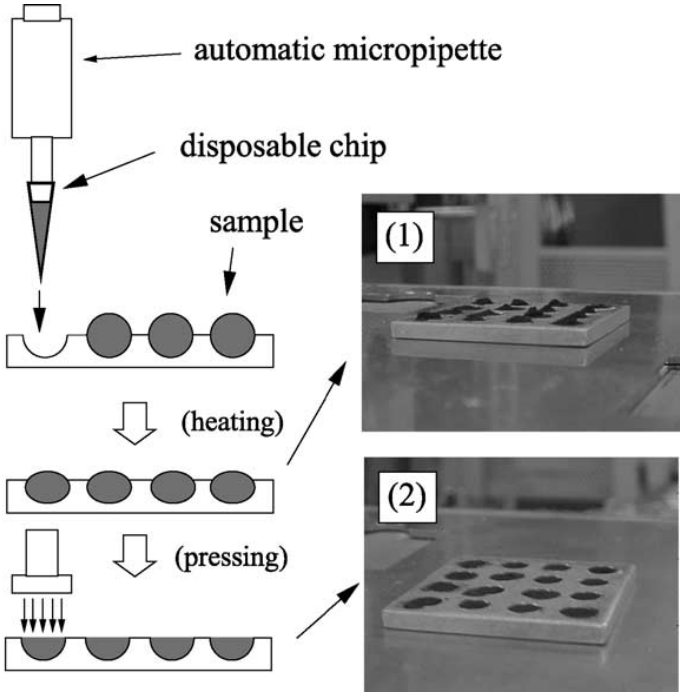
Coin cell



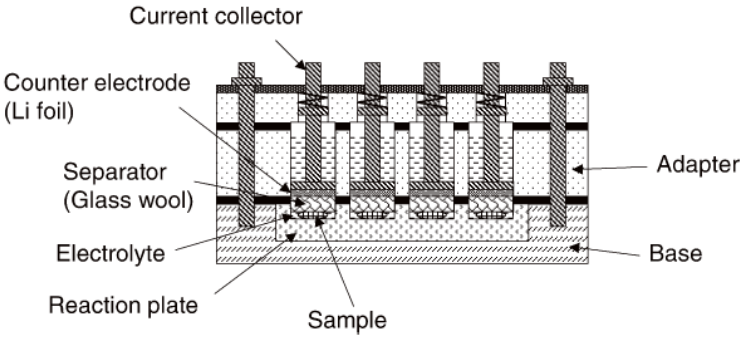
Full cell (Sony)

Powder electrodes

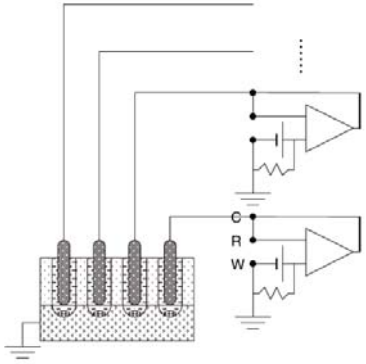
I. Yanase / M. Watanabe, Ibaraki, Japan



Yanase *et al.* Solid State Ionics, **151** 189 (2002).

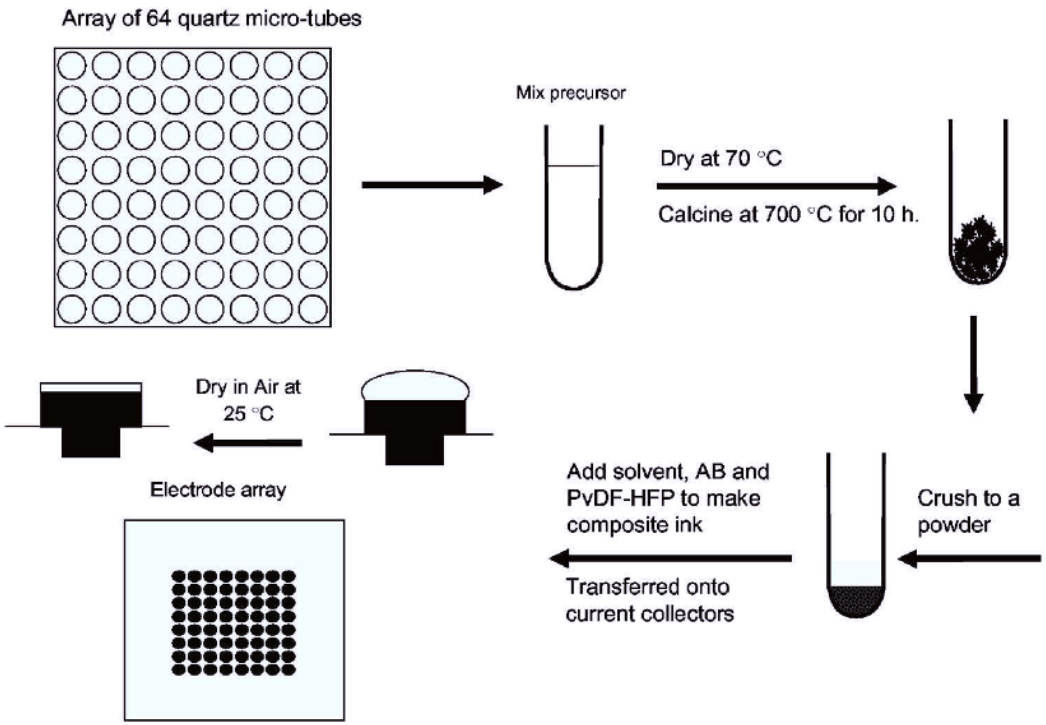


Takada *et al.*, App. Surf. Sci., **223**, 210 (2004).



Powder electrodes

John Owen, U. Southampton, UK



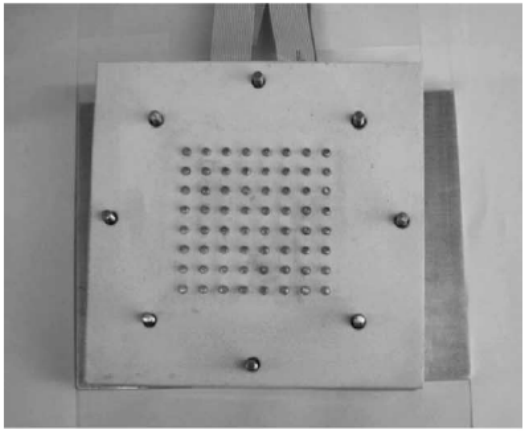
C-$LiFePO_4$

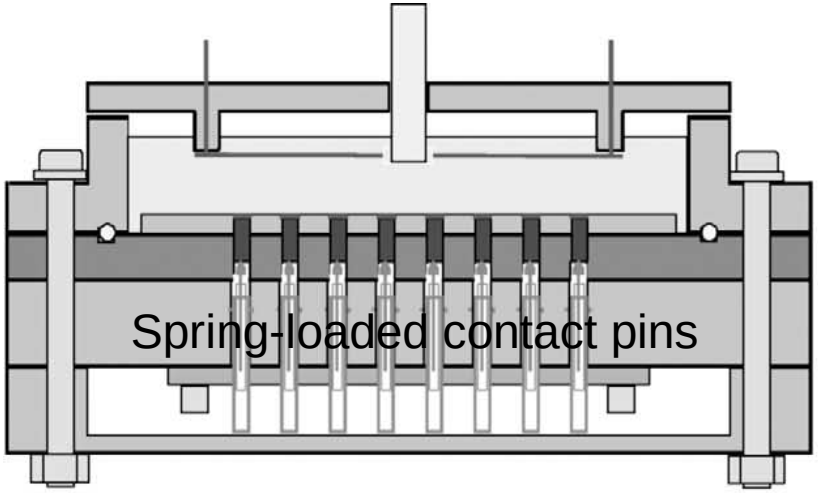
(C)-(Li-Mg)-$FePO_4$

Roberts *et al.*, J. Electrochem. Soc., **154**, A921 (2007).

Powder electrodes

John Owen, U. Southampton, UK



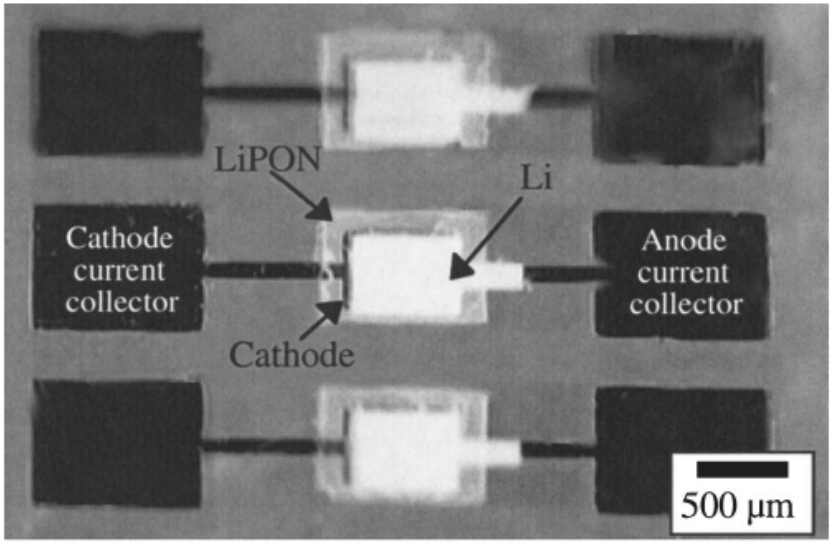


Spong *et al.*, J. Power Sources, **119**, 778 (2003).

Thin film electrodes / cells

W. West / Jay Whitacre, JPL

- All solid-state cells, $Li_yMn_xNi_{2-x}O_4$ vs. Li
- Co-sputtered
- Serial cycling
- Problem matching thin film and bulk results (solution?)

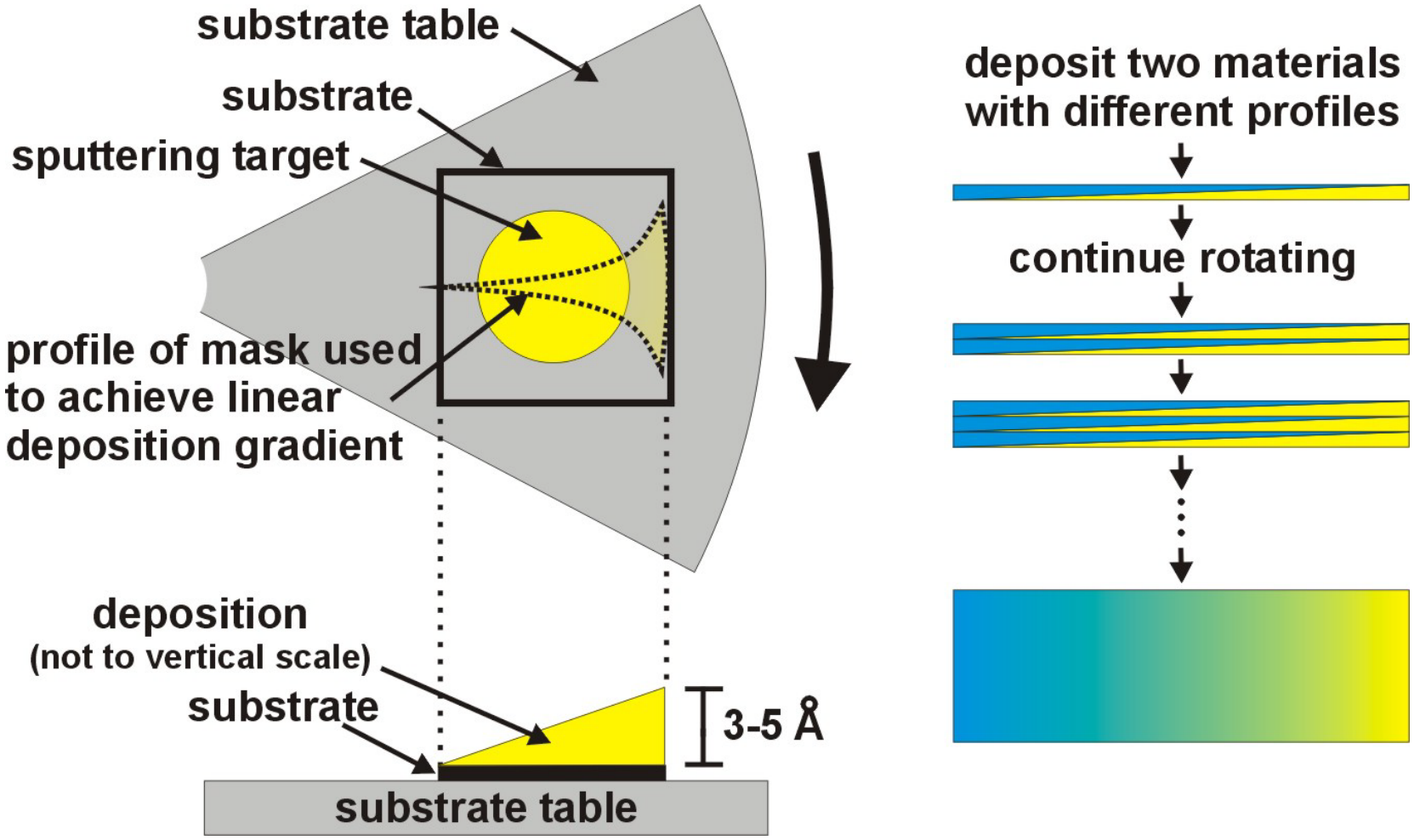


West *et al.*, J. Micromech. Microeng., **12**, 58 (2002), Whitacre *et al.*, J. Electrochem. Soc., **150**, A1676 (2003).

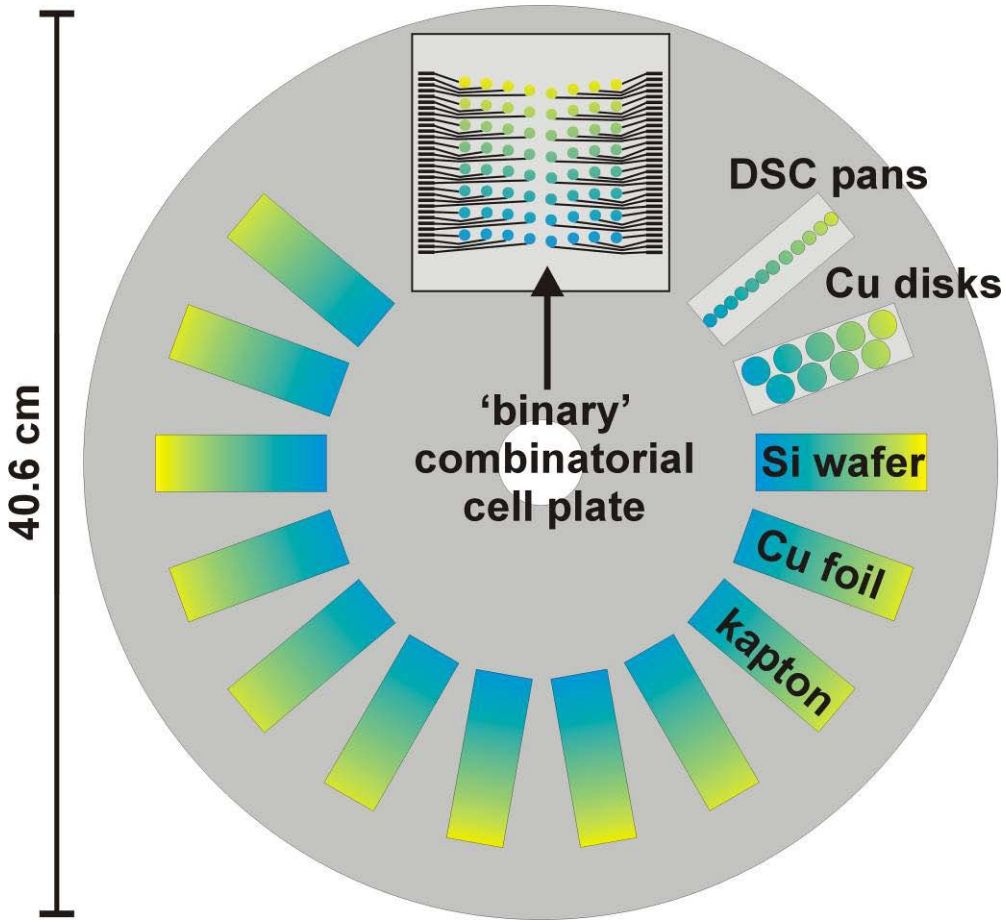
Thin film electrodes

Jeff Dahn, Dalhousie U., Halifax, NS Canada

- Composition spread, sputtered
- Mostly looking at amorphous metal alloys
- Same thin film to bulk issues
- Si-(Ag, Al, C, Co, Cr, Fe, Mn, Ni, Sn, Zn), Sn-(Co, Cr, Cu, Fe, Mo, Mn, Ni, Ti, V), Si-Sn-(Al, MM), Al-(Si)-(Cr, Fe, Mn, Ni), Sn-C-(Co, Ti, V), LiF-(C)-(Fe, Co, Ni)



Method: Dahn *et al.,* Chem. Mat. **14**, 3519 (2003).



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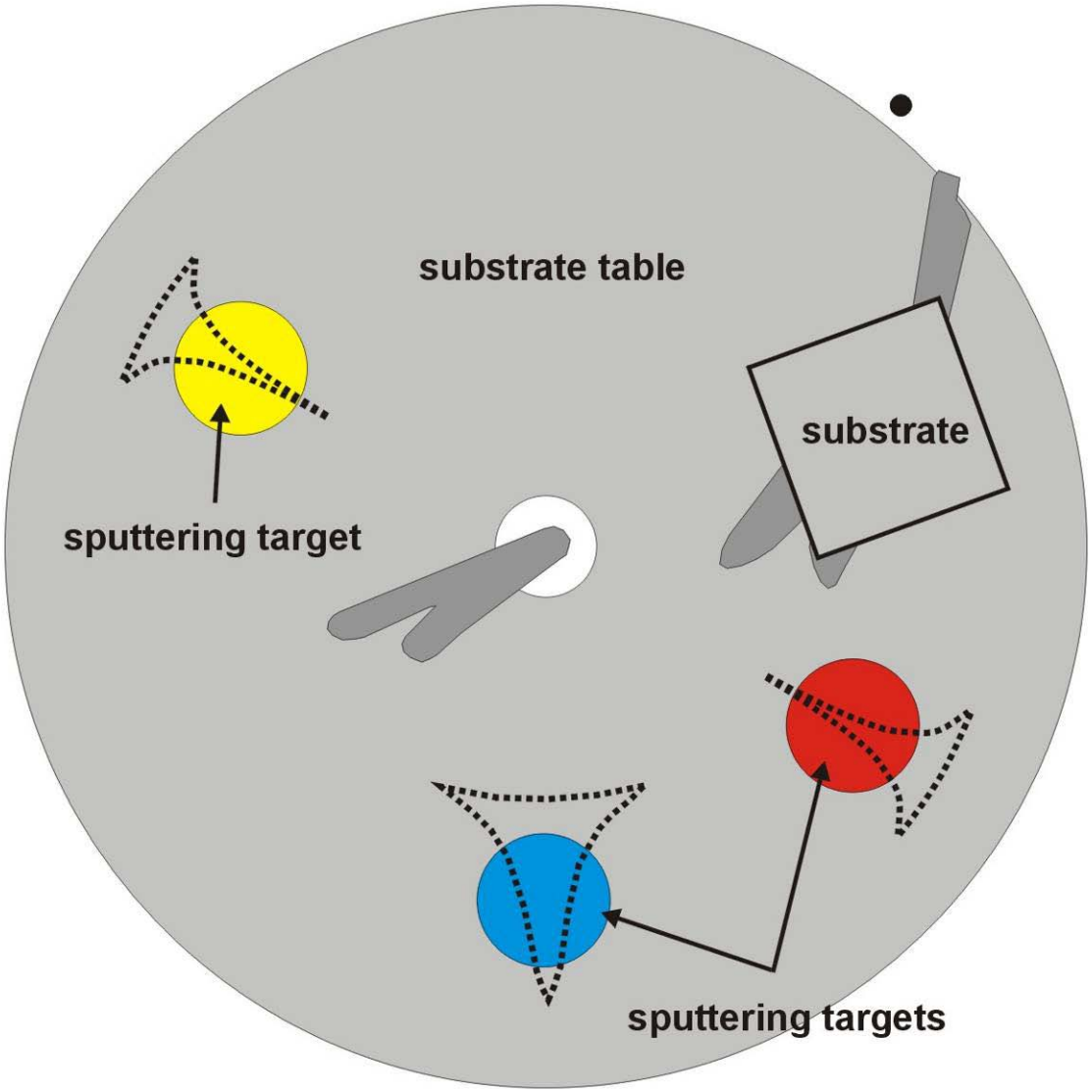
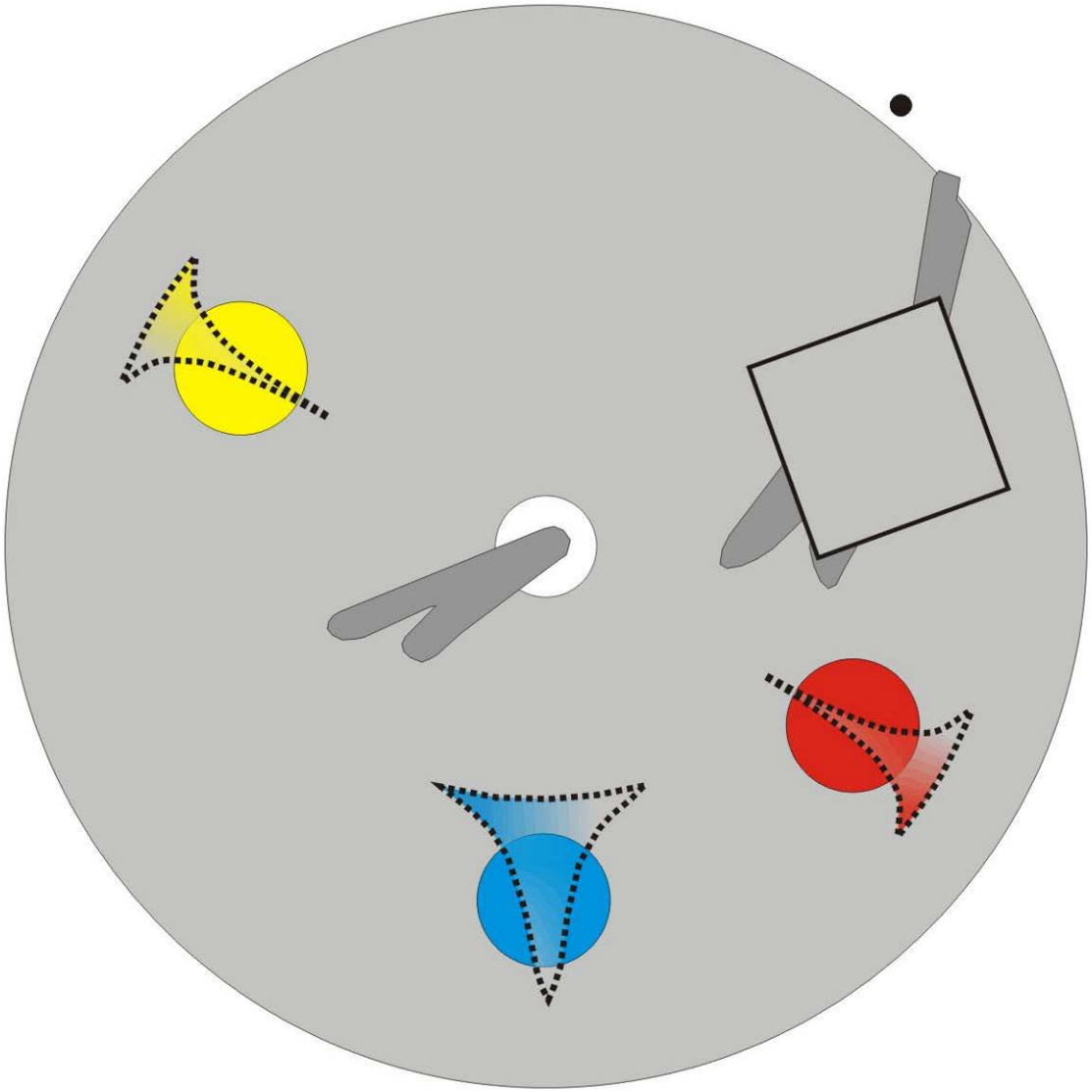
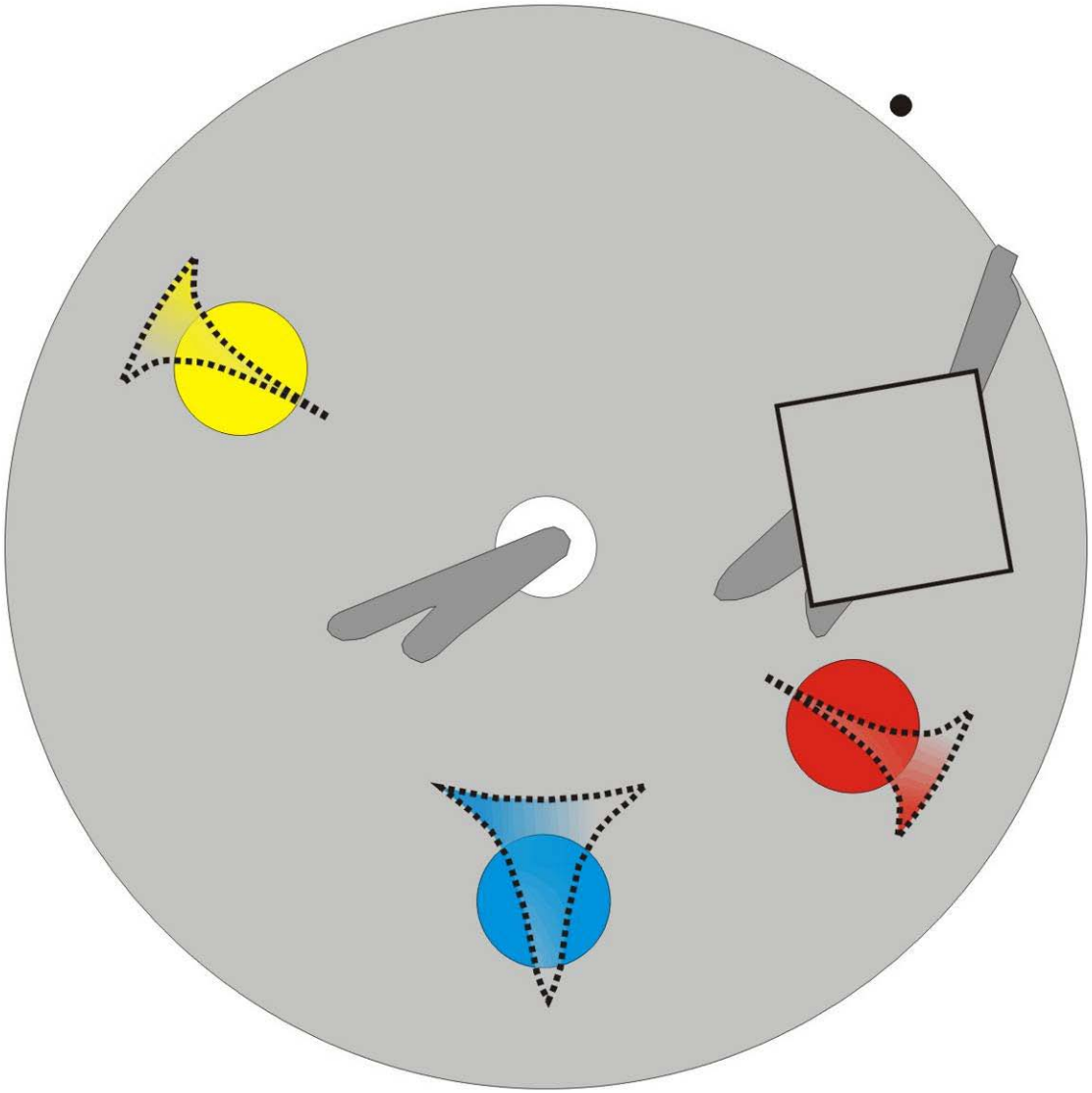
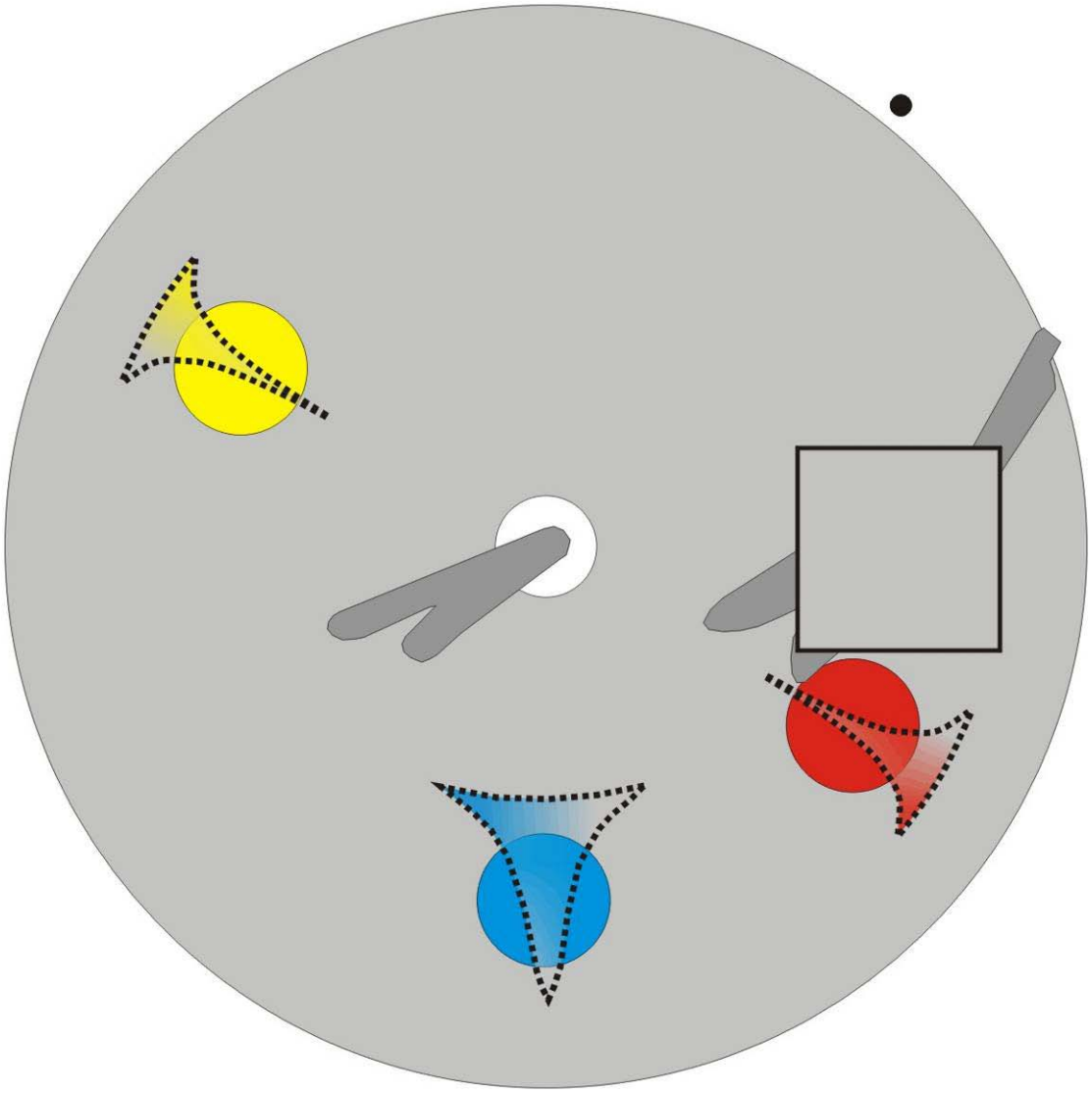
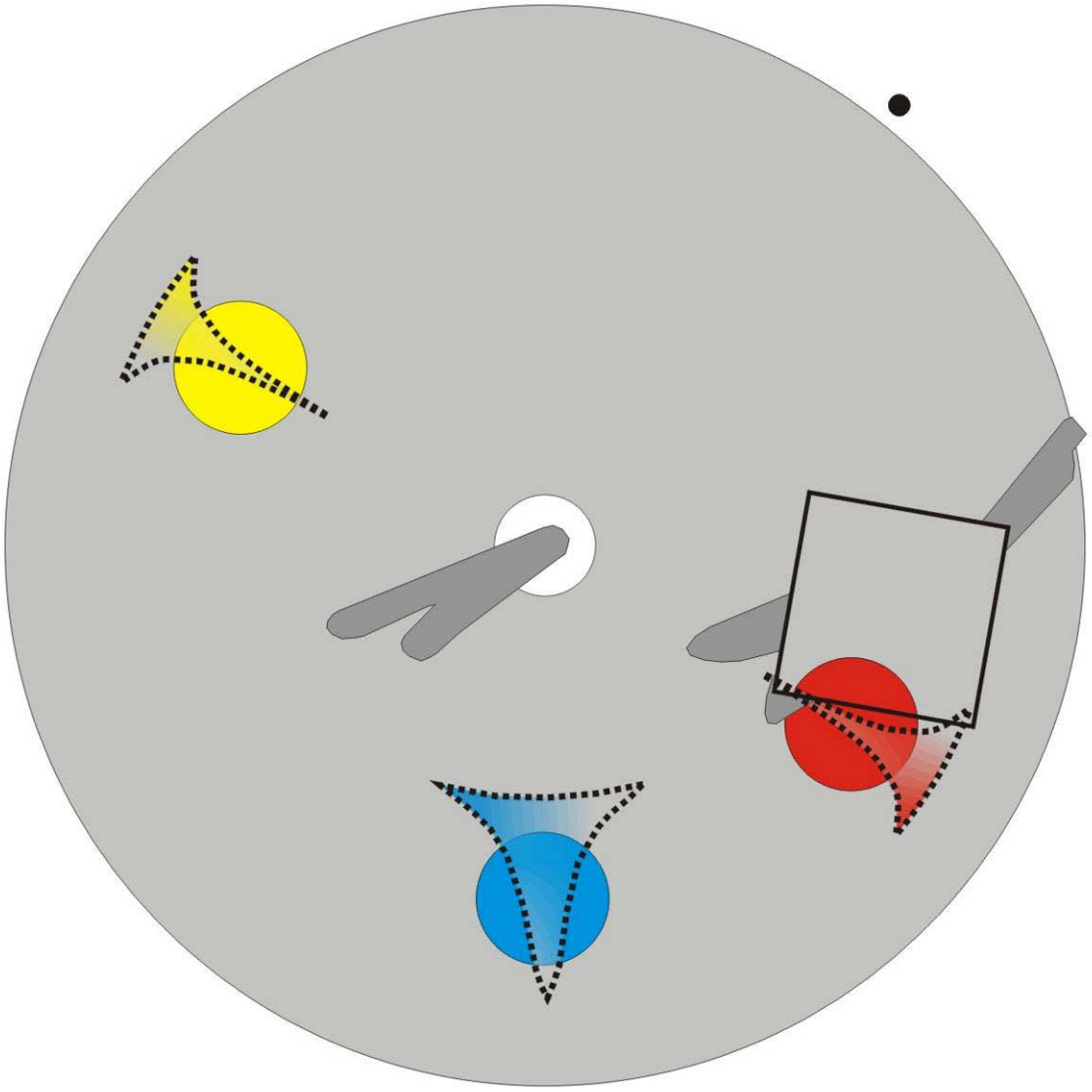
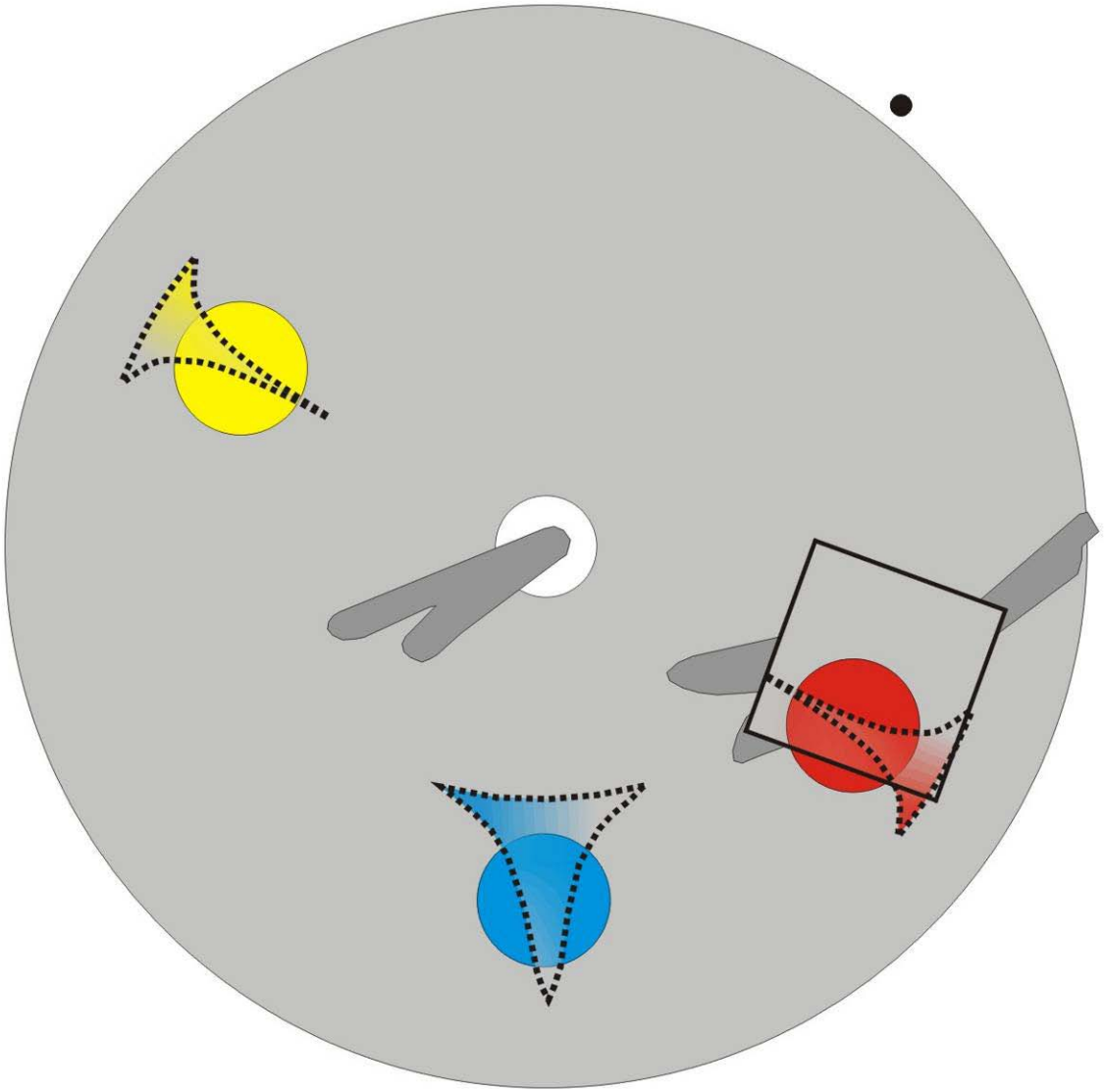

substrate table
substrate
sputtering target
sputtering targets

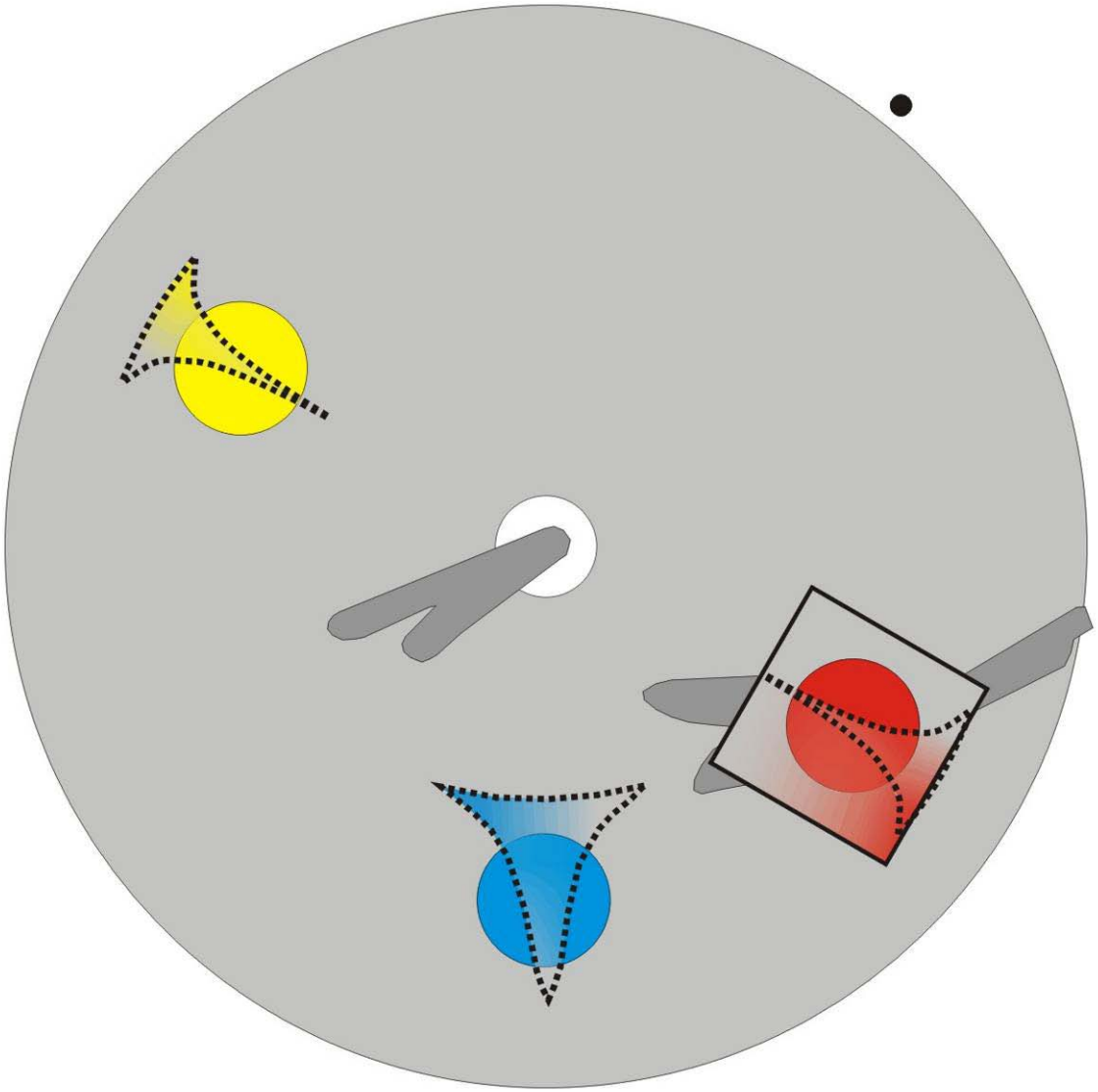


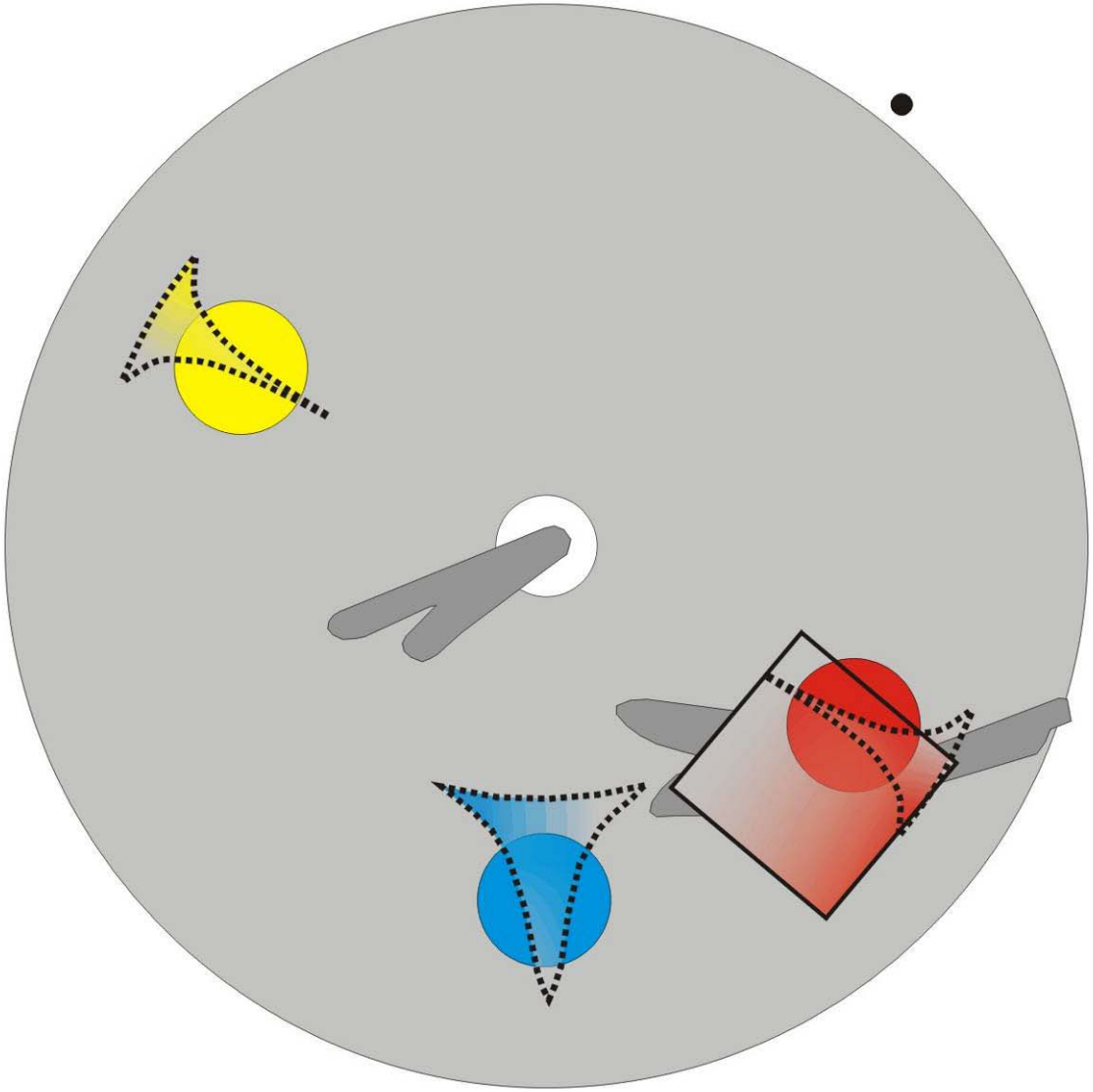


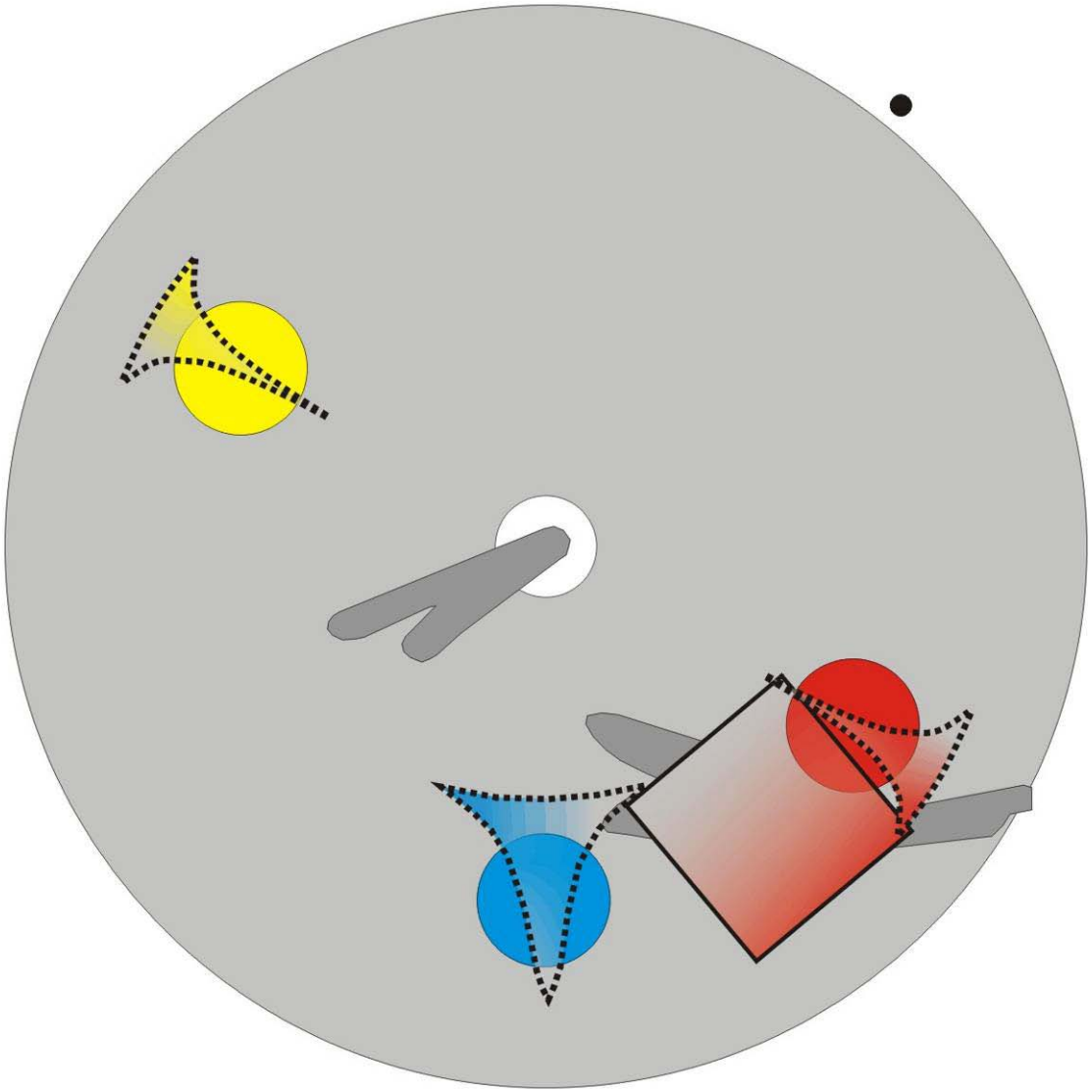


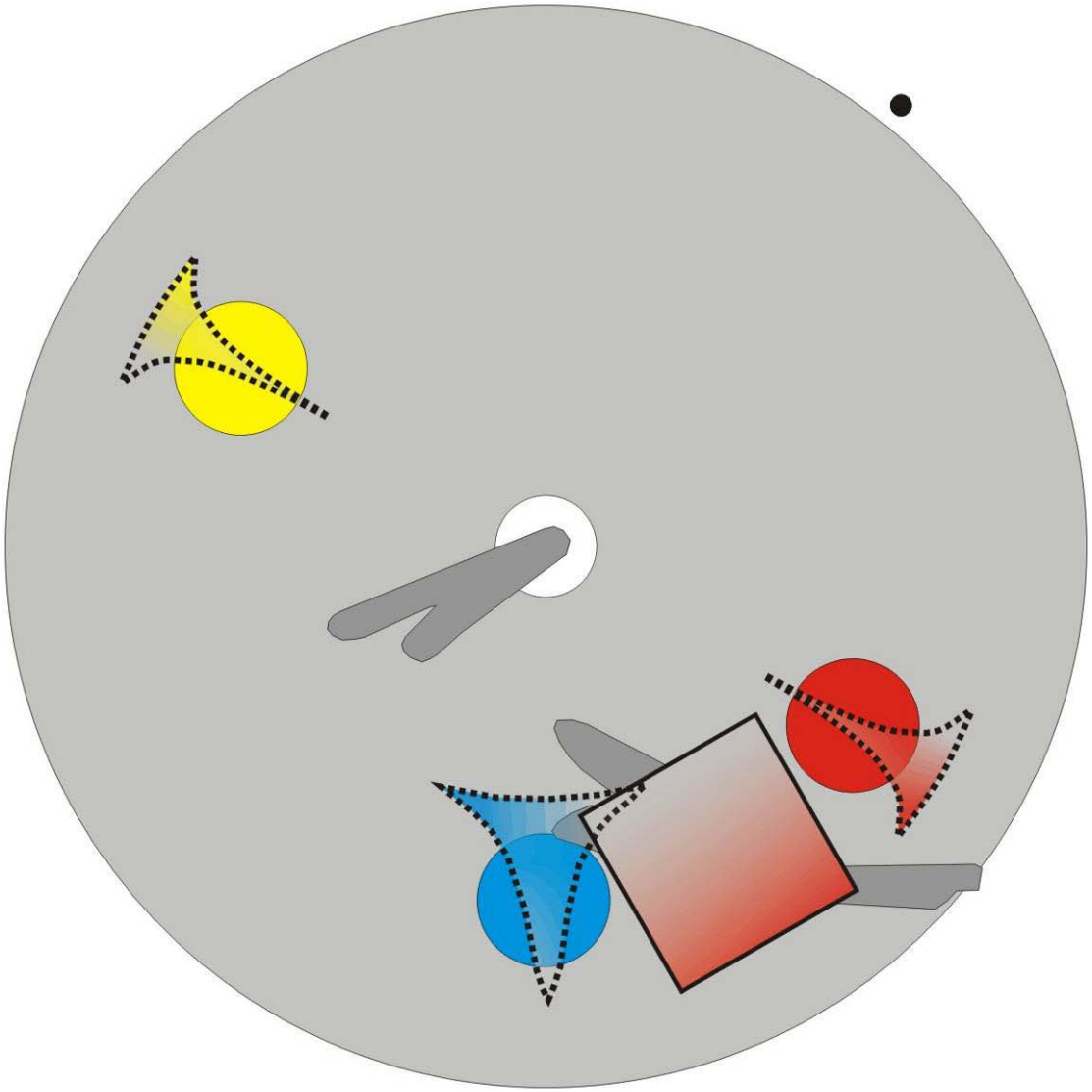


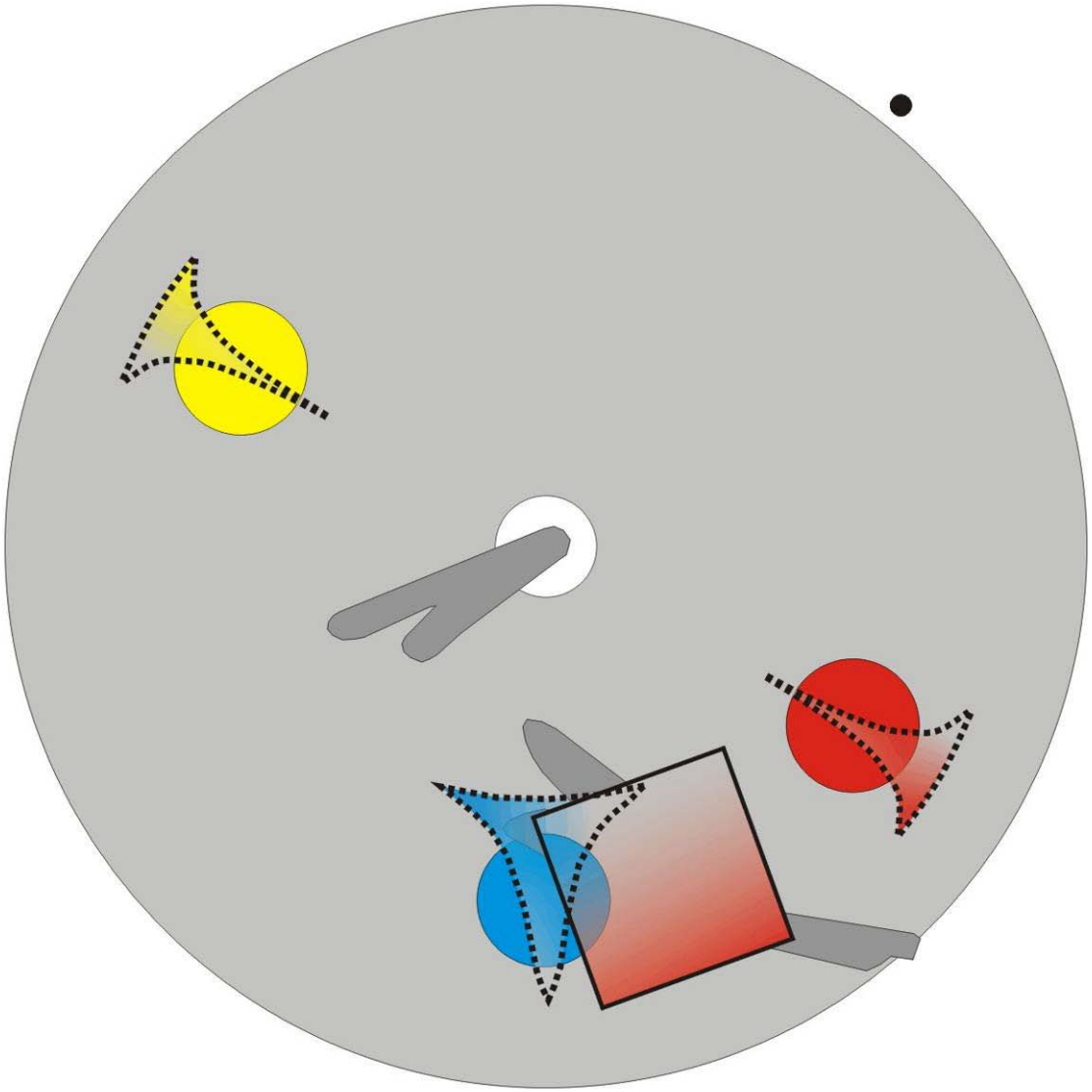


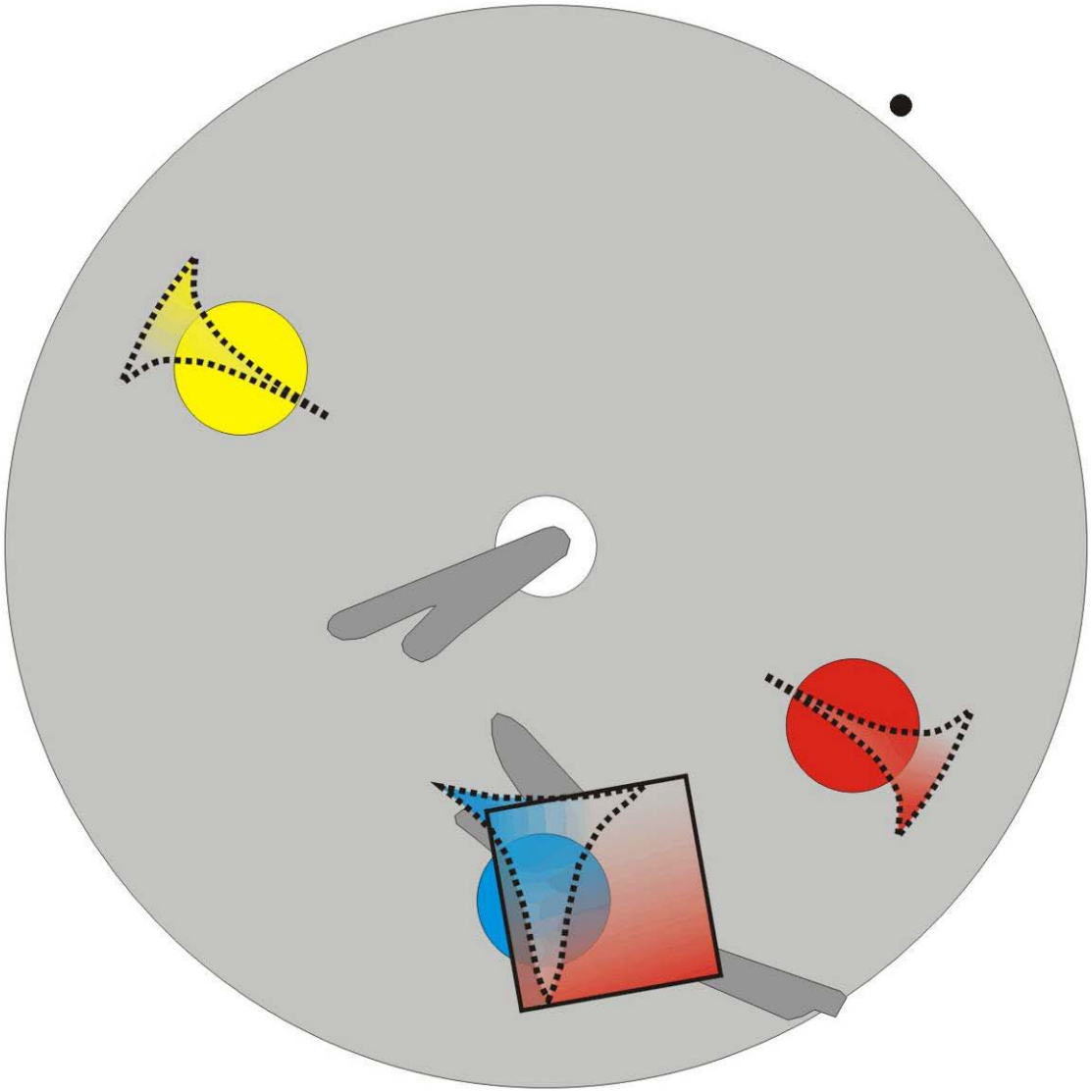


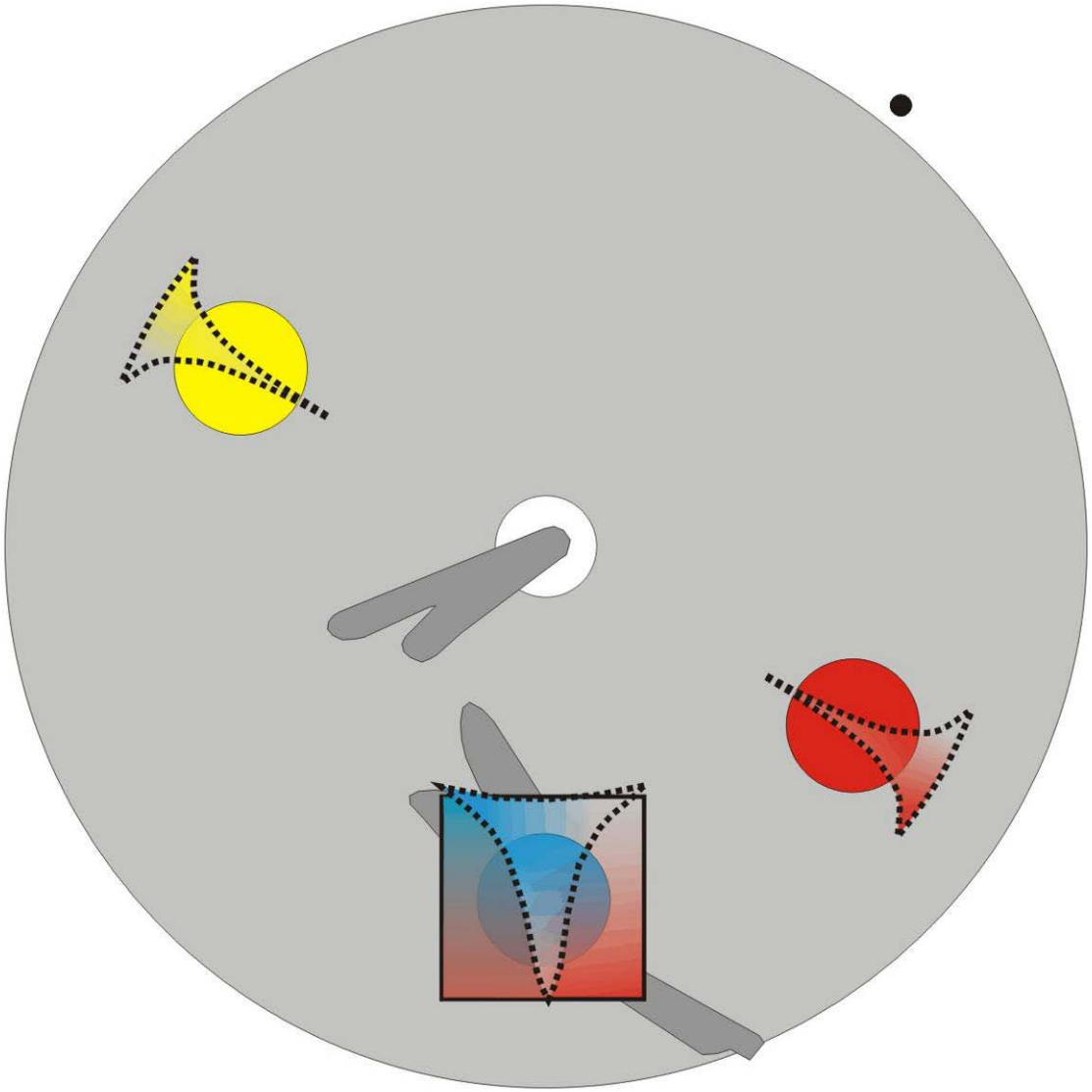


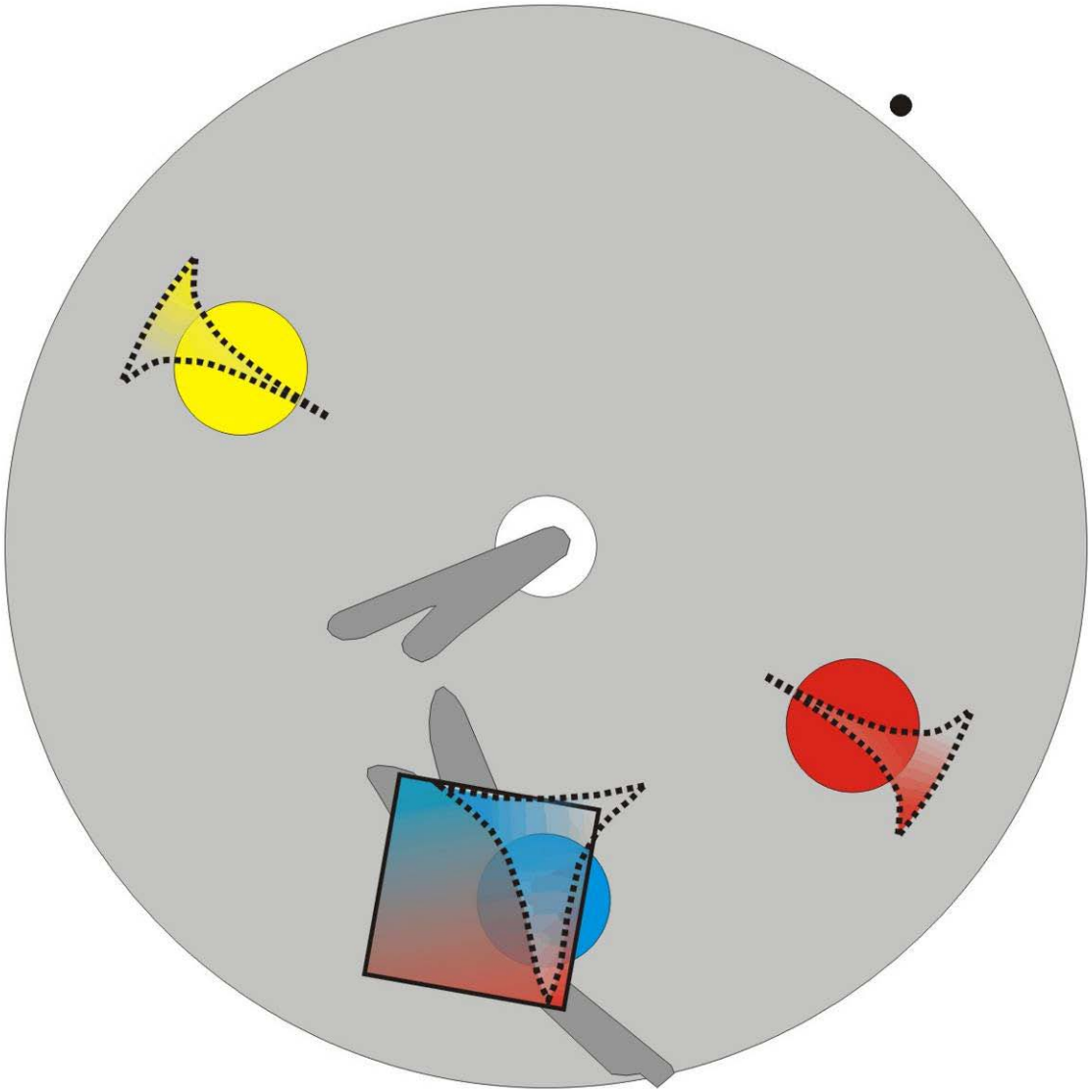


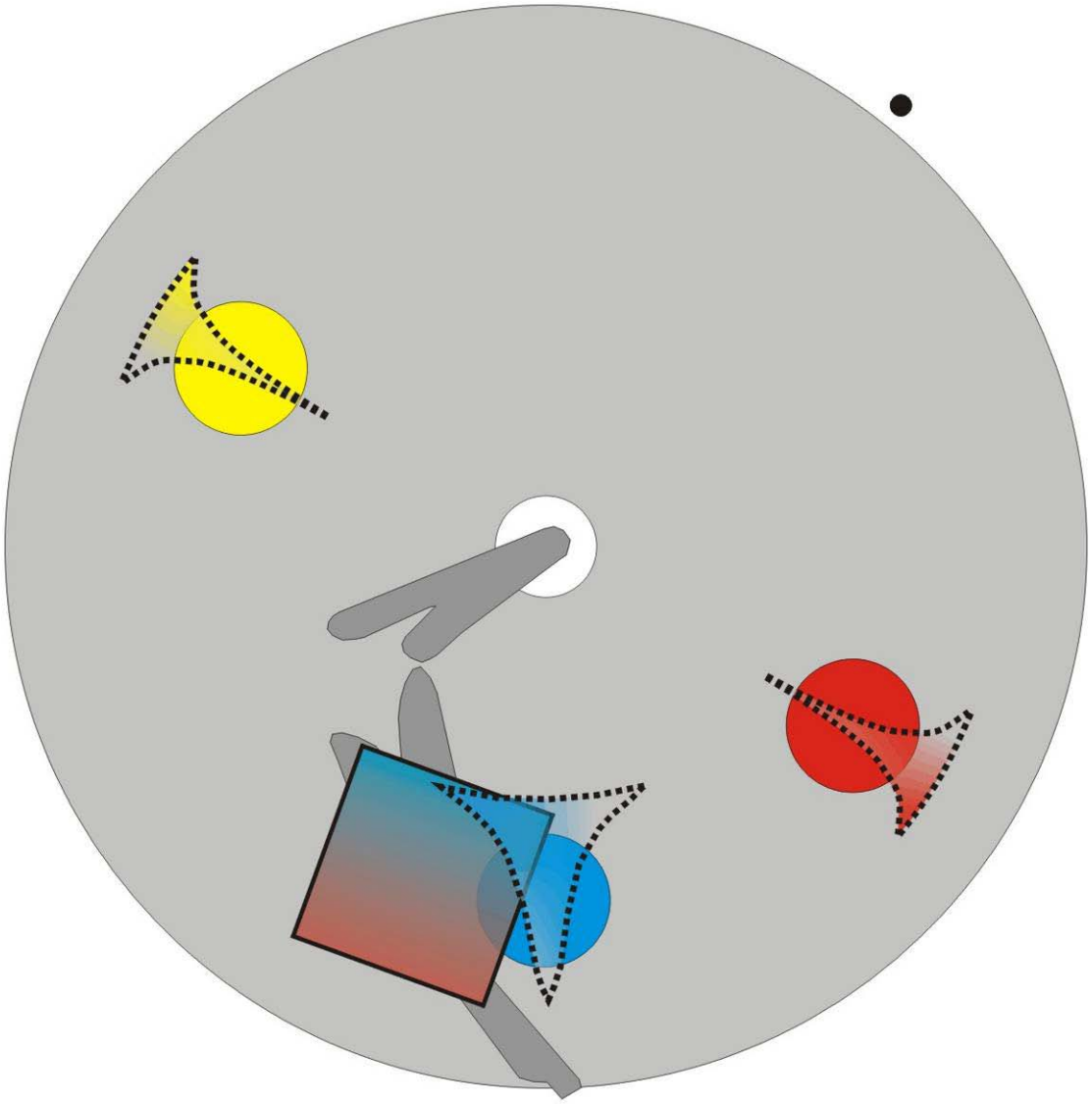


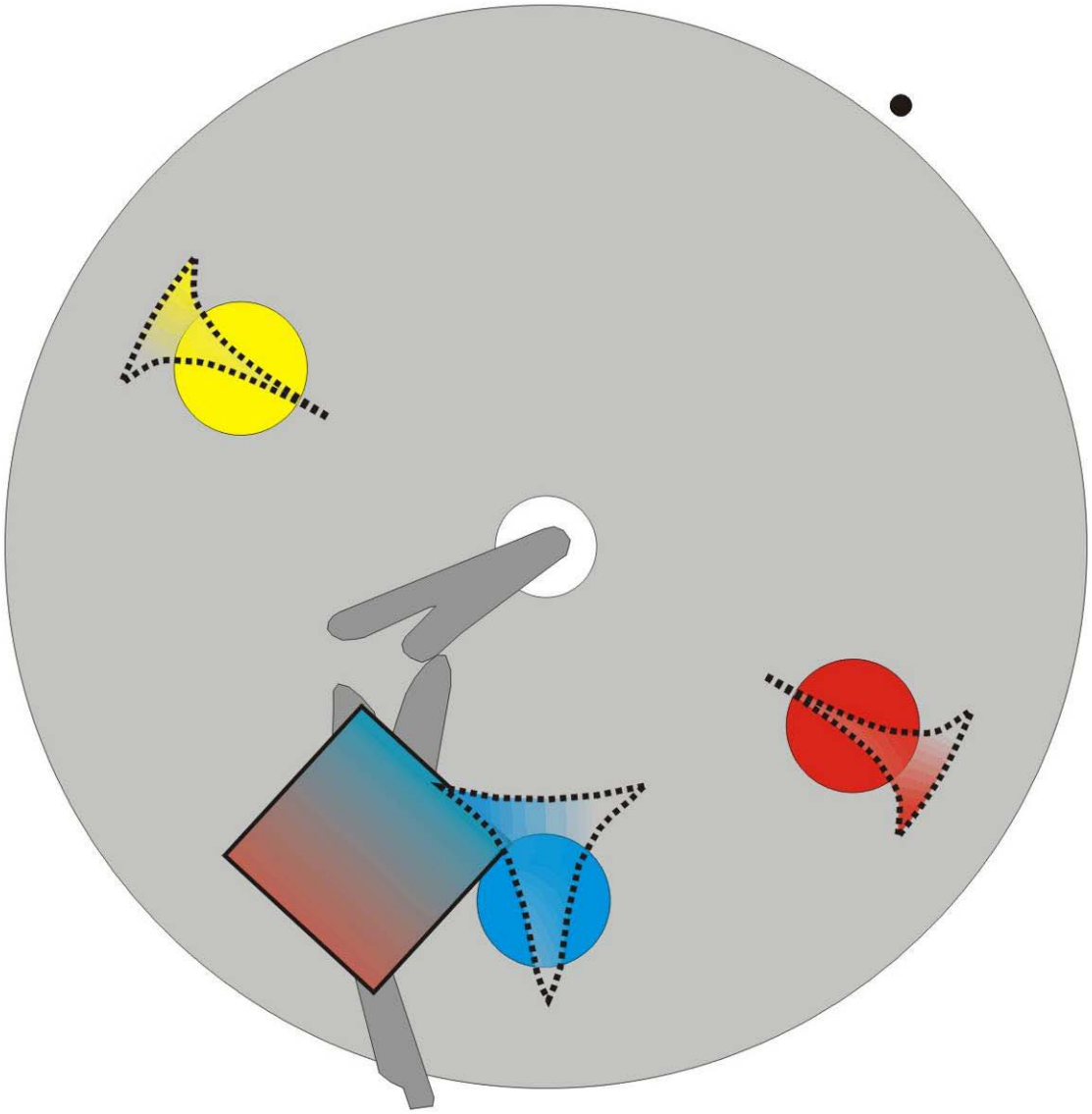


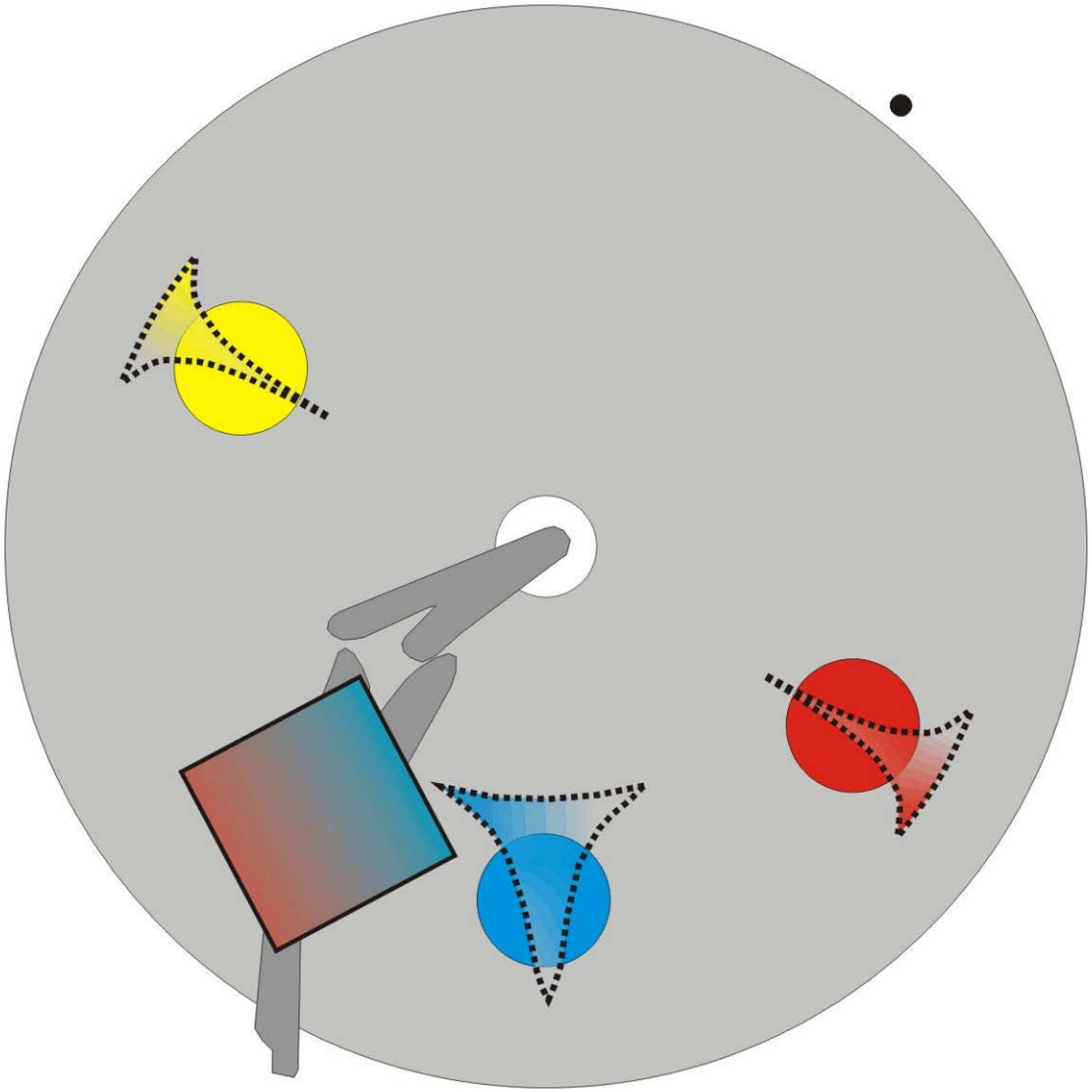


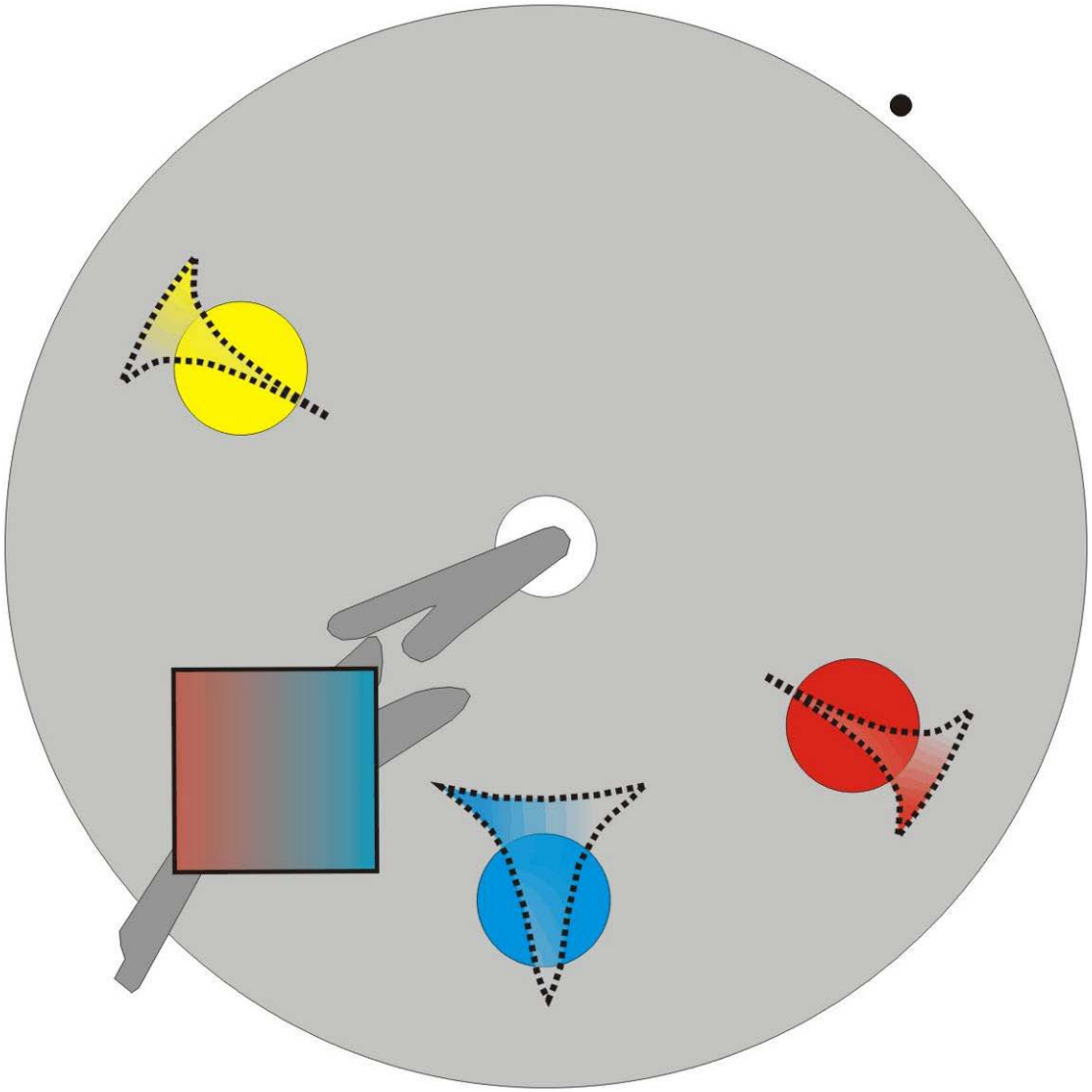


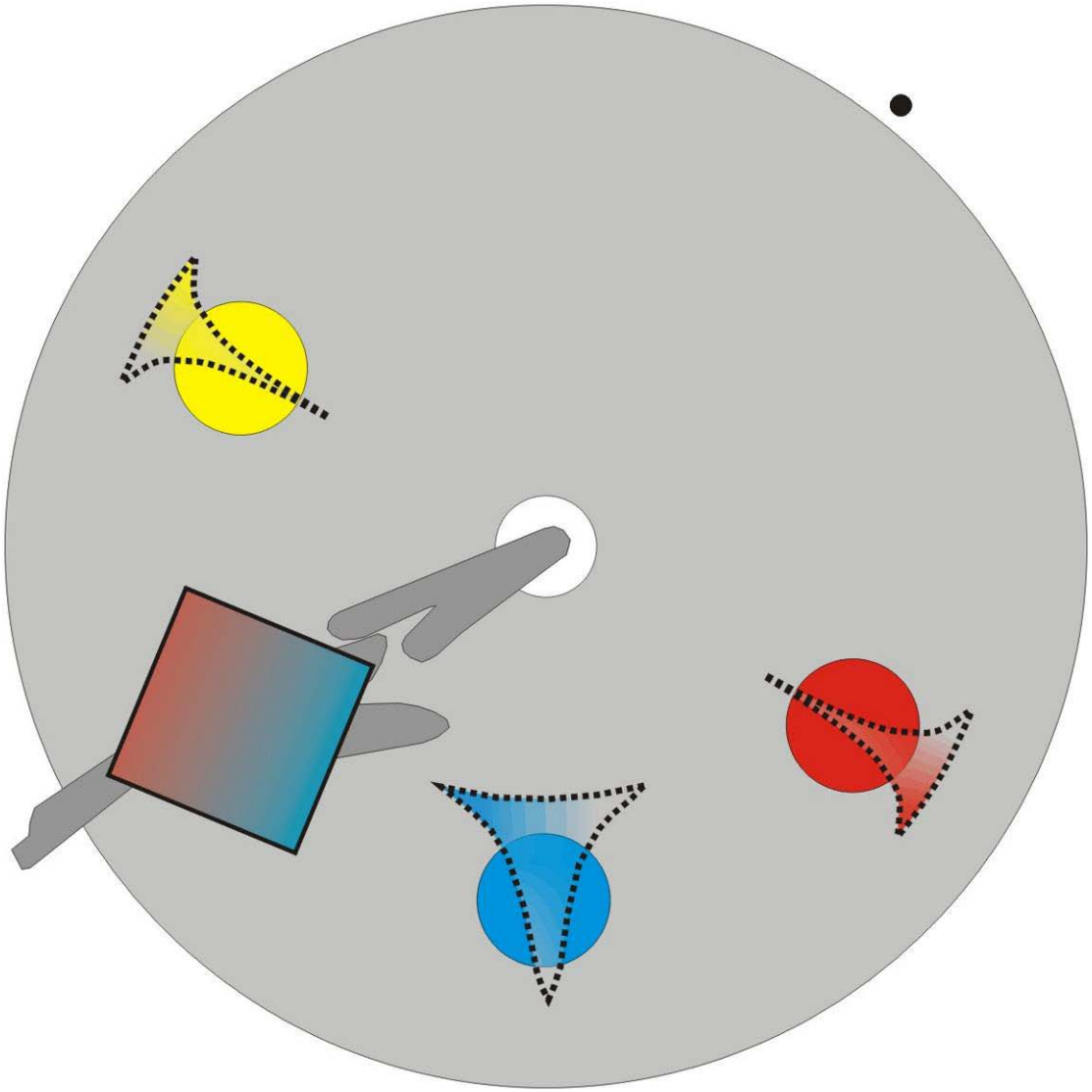


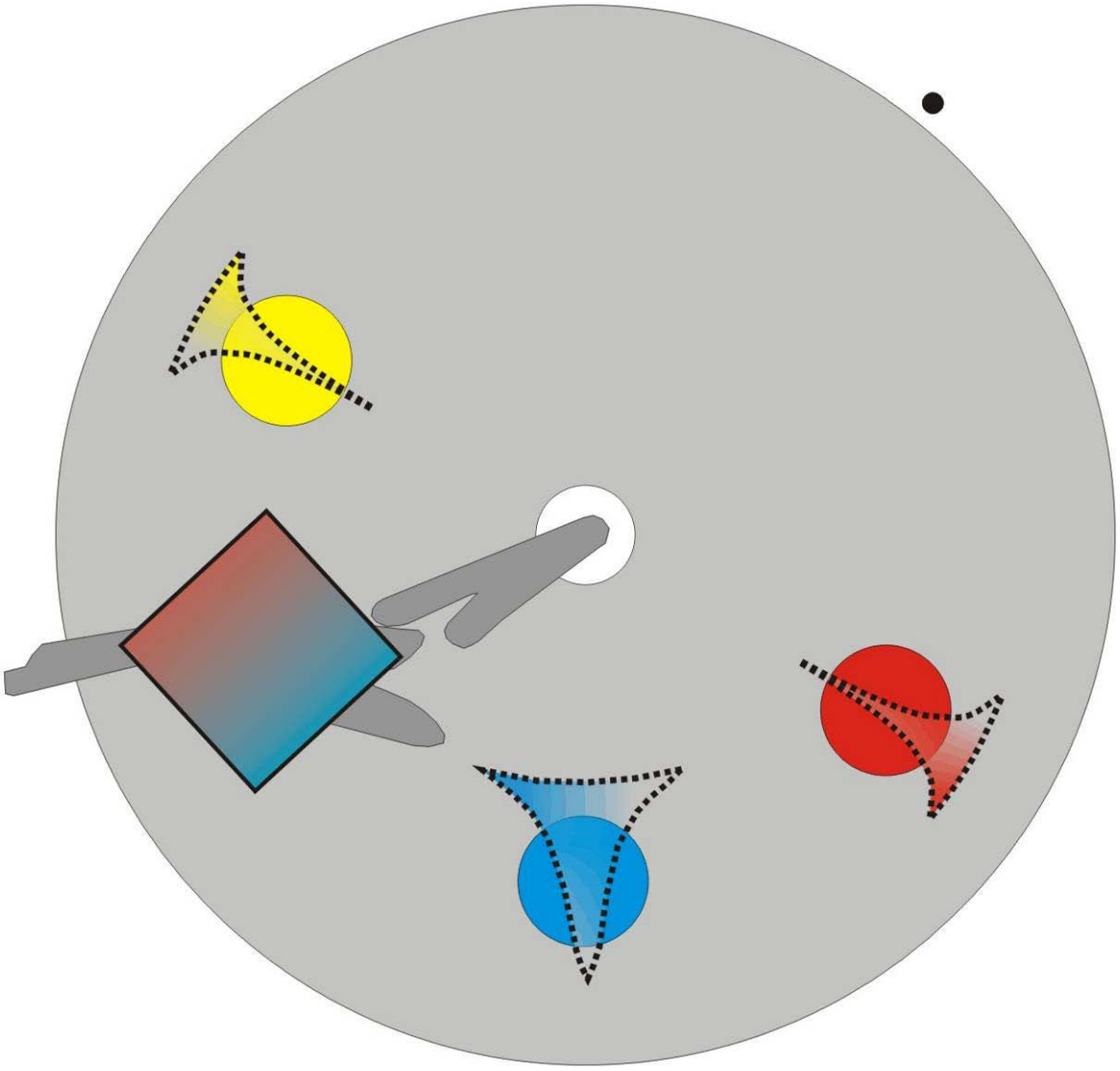


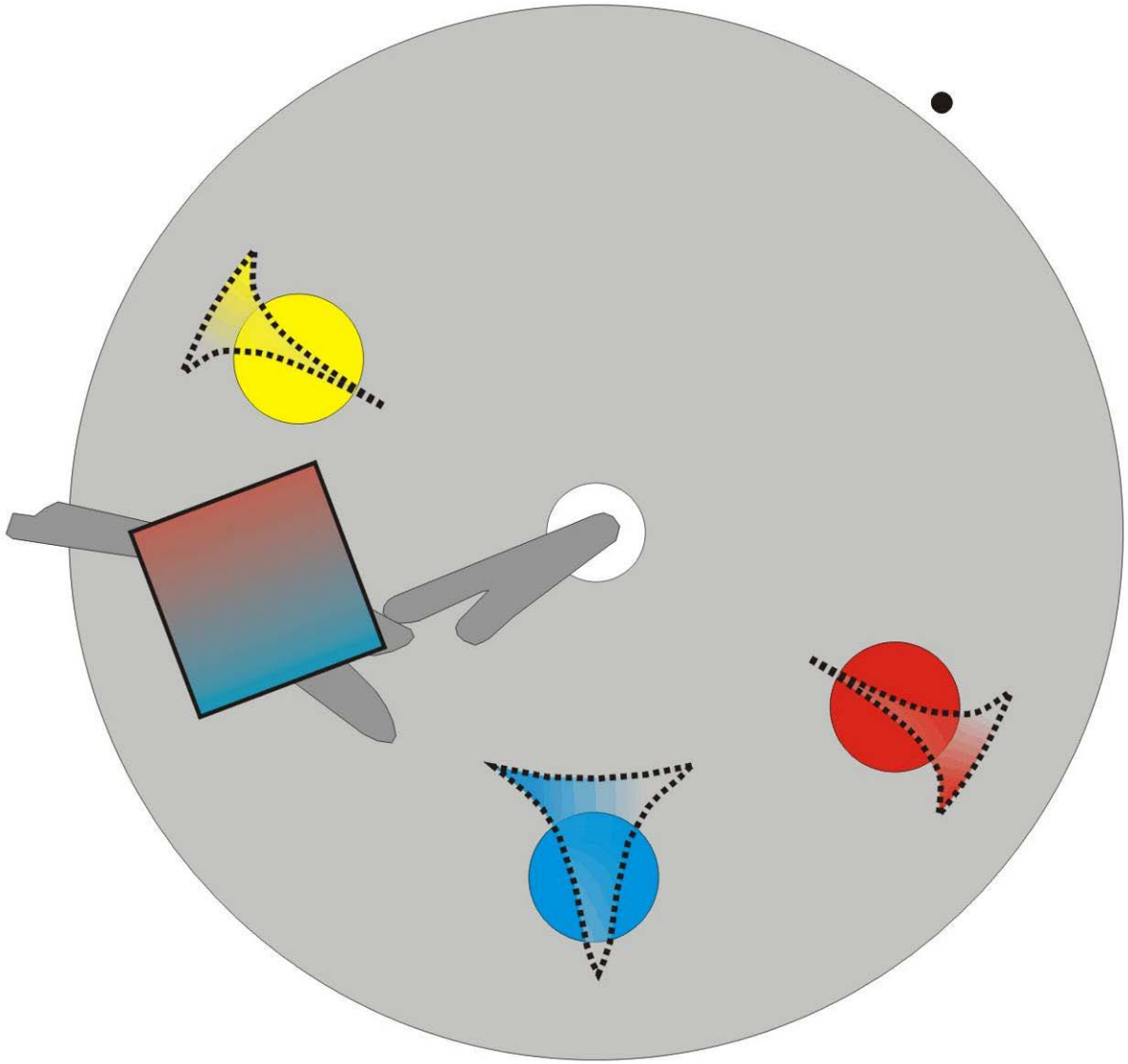


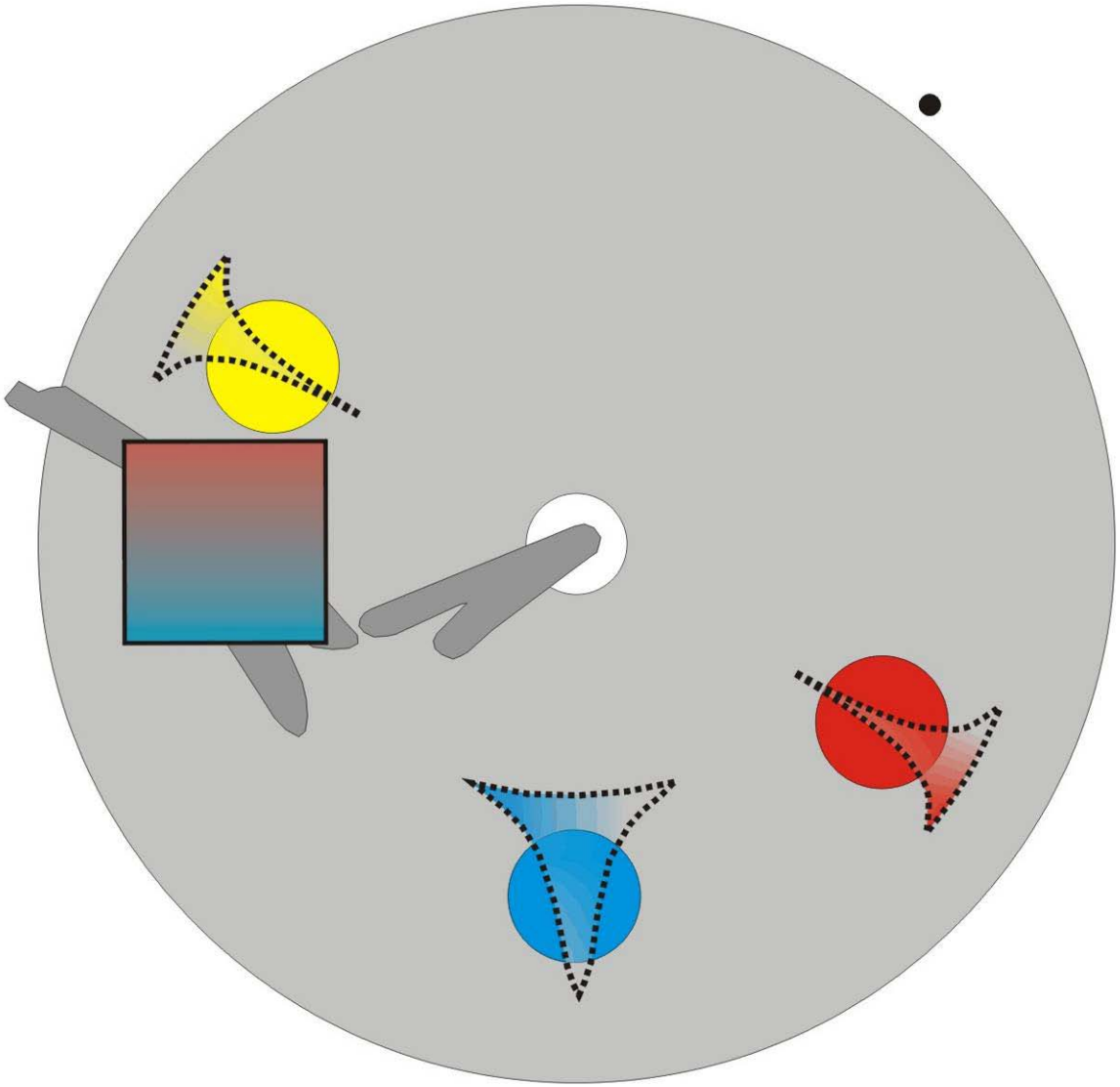


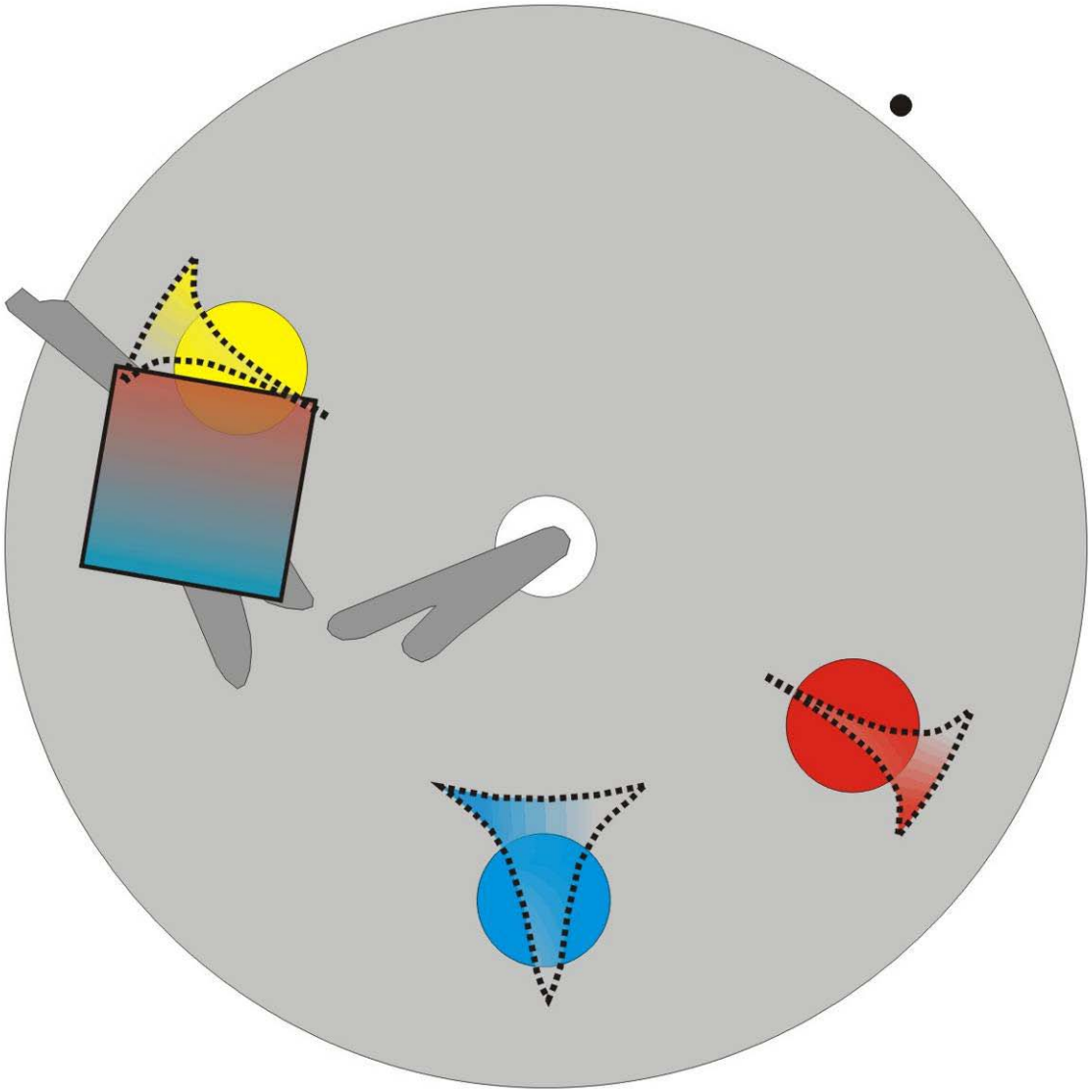


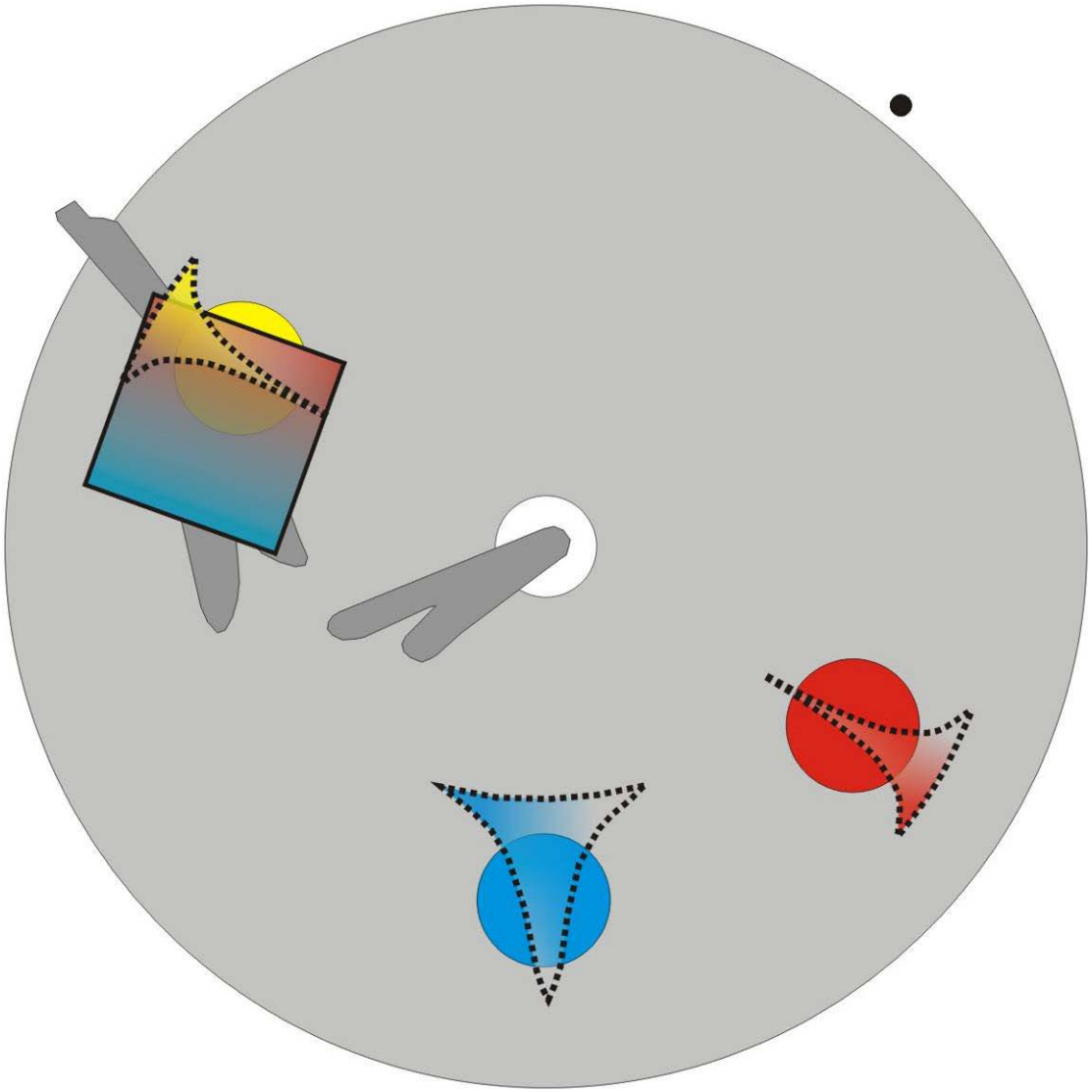


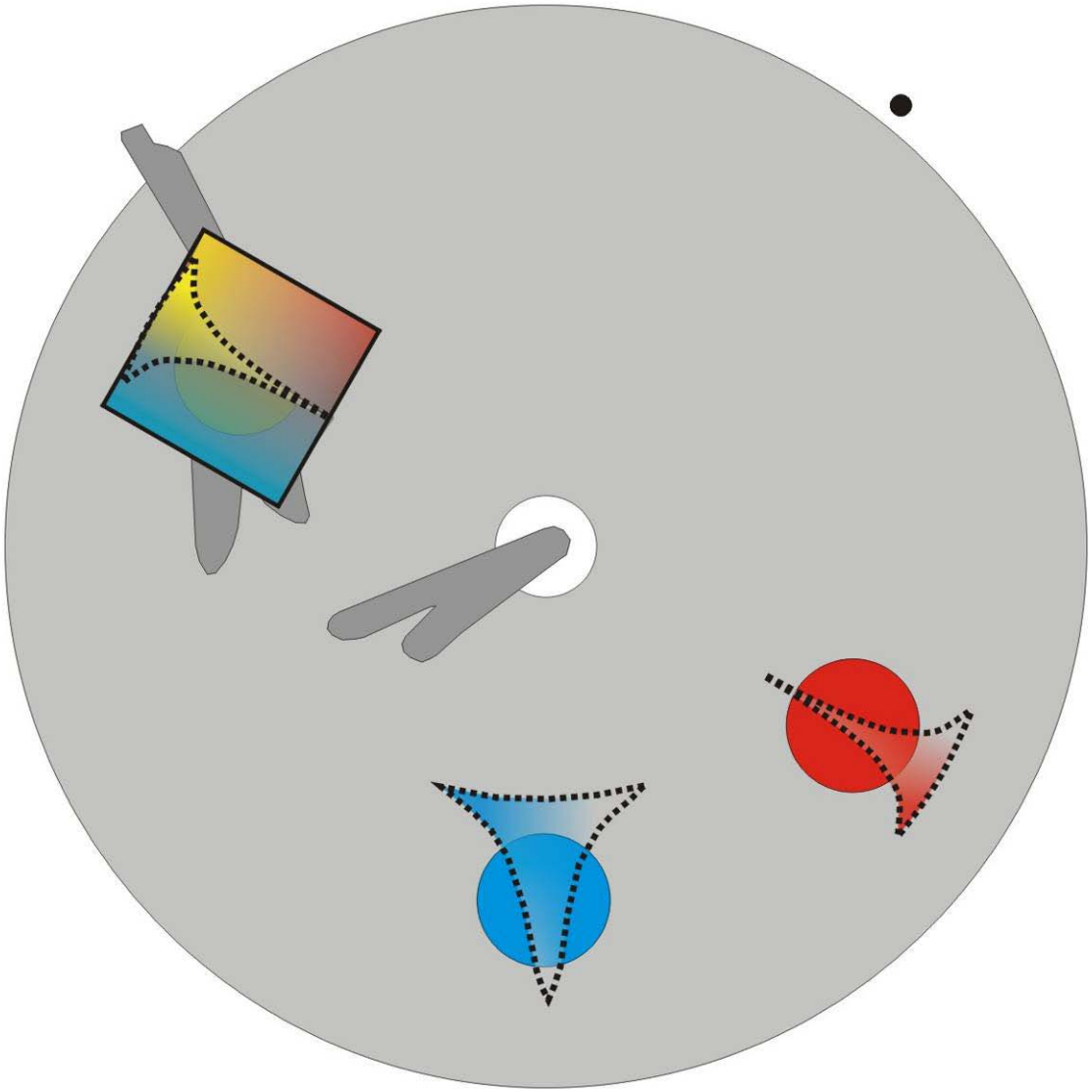


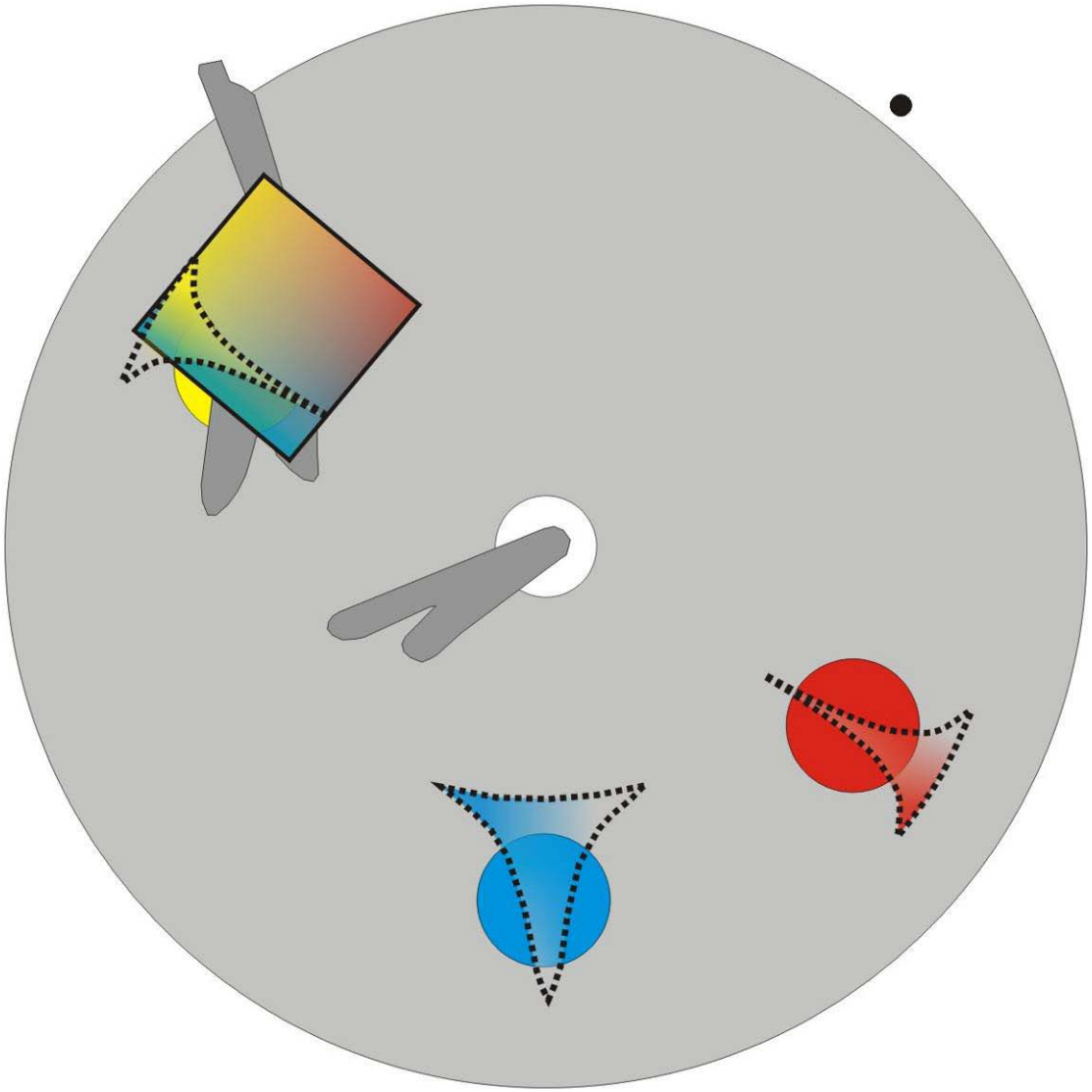


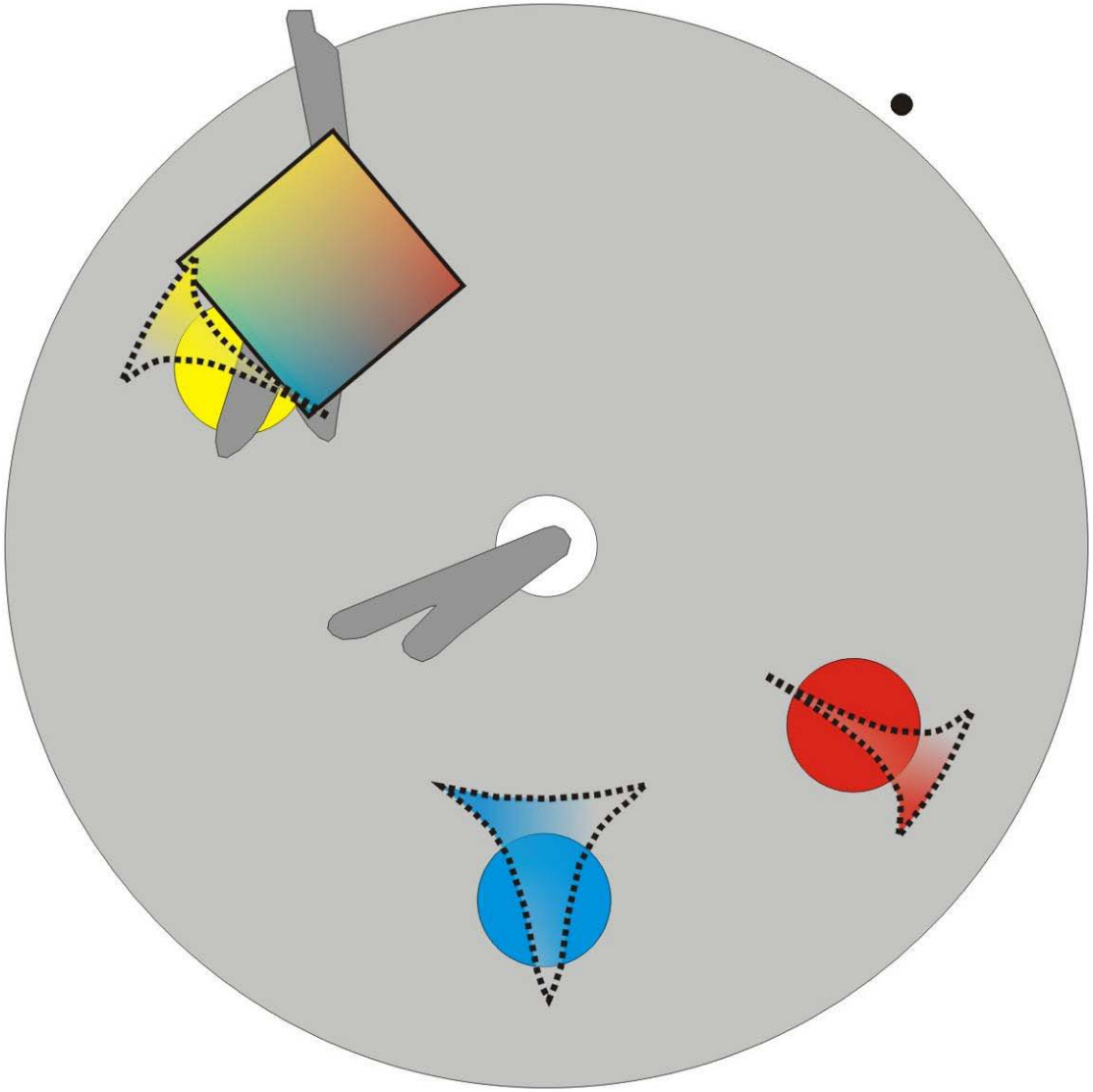


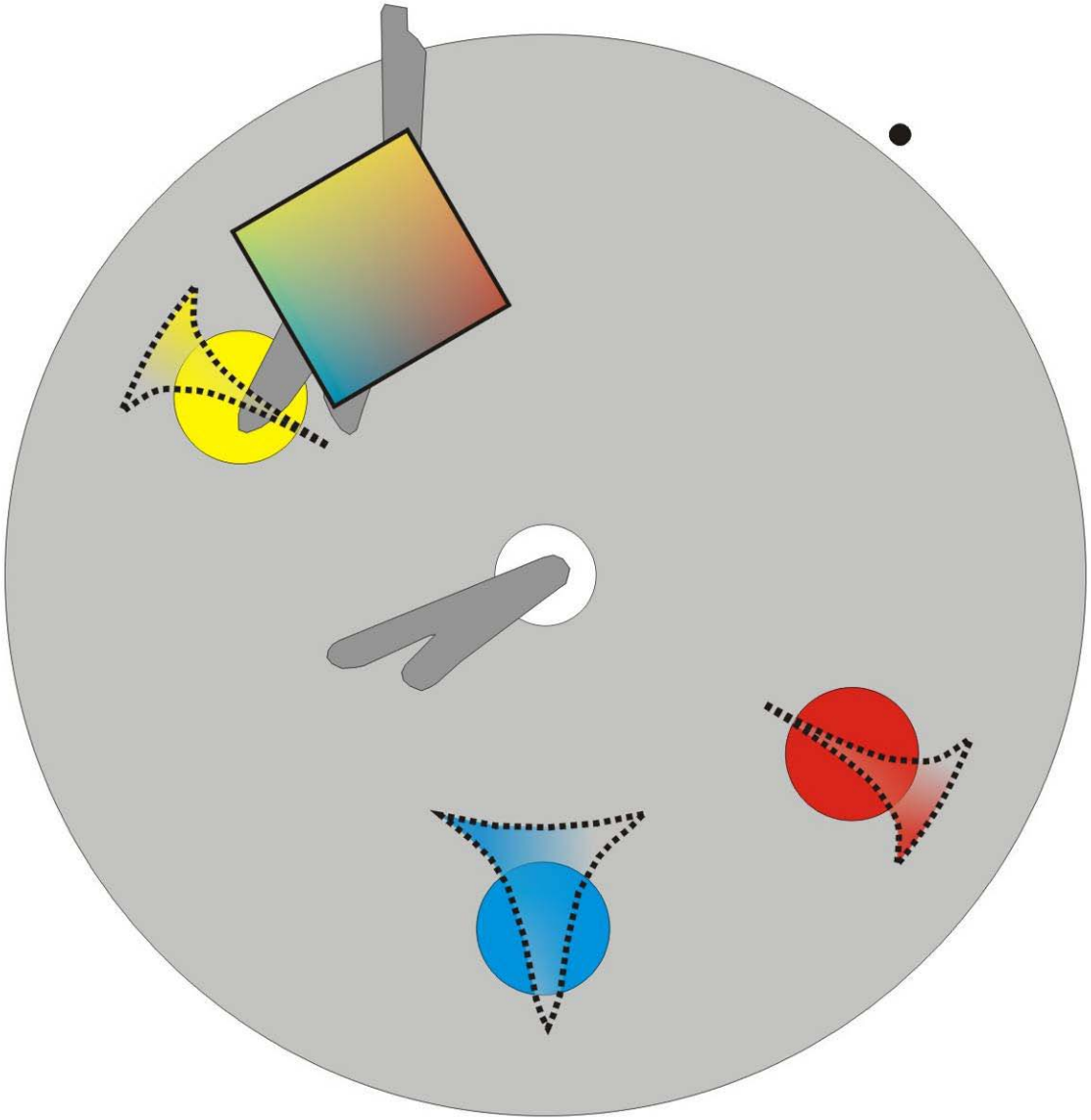


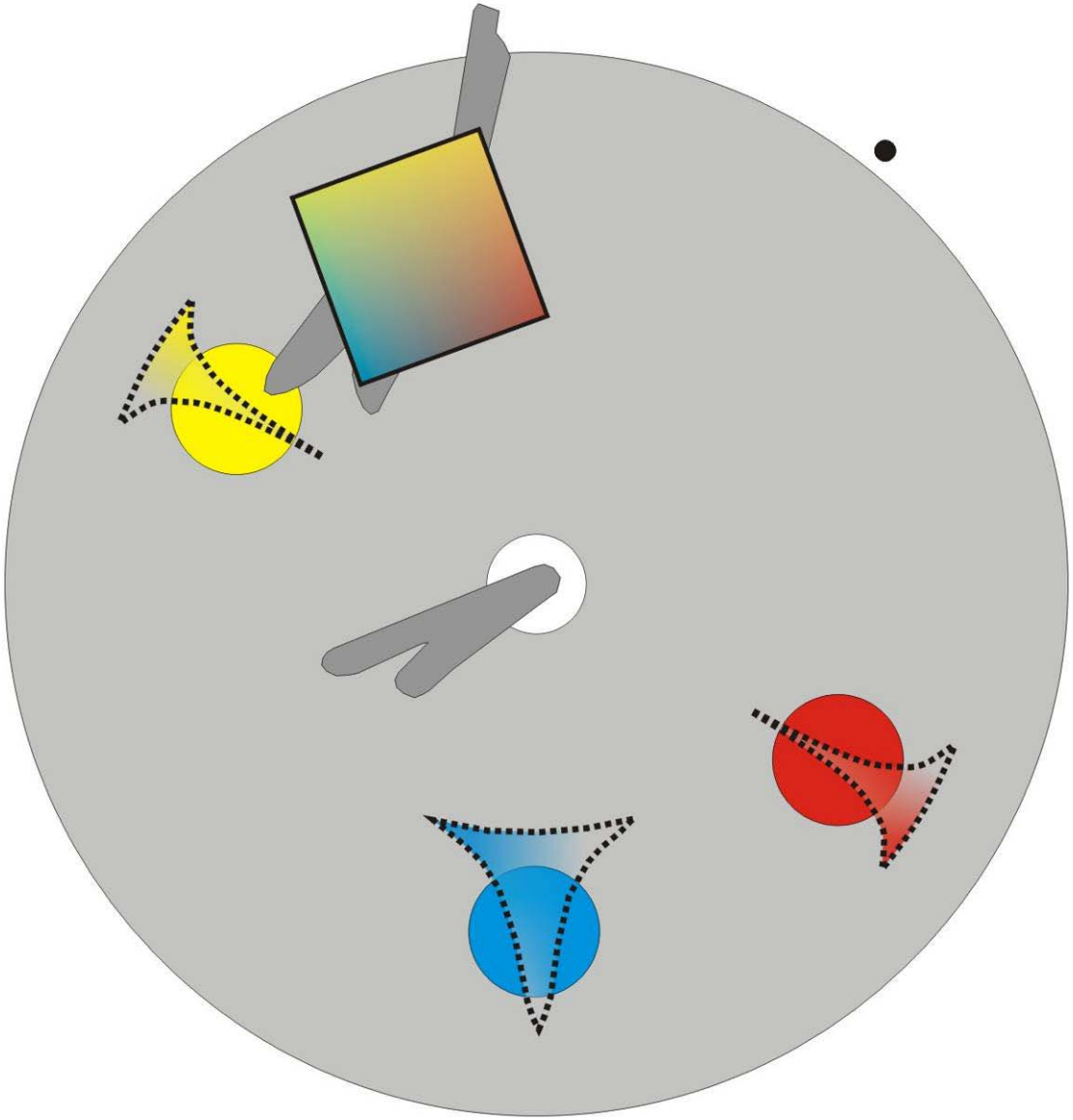


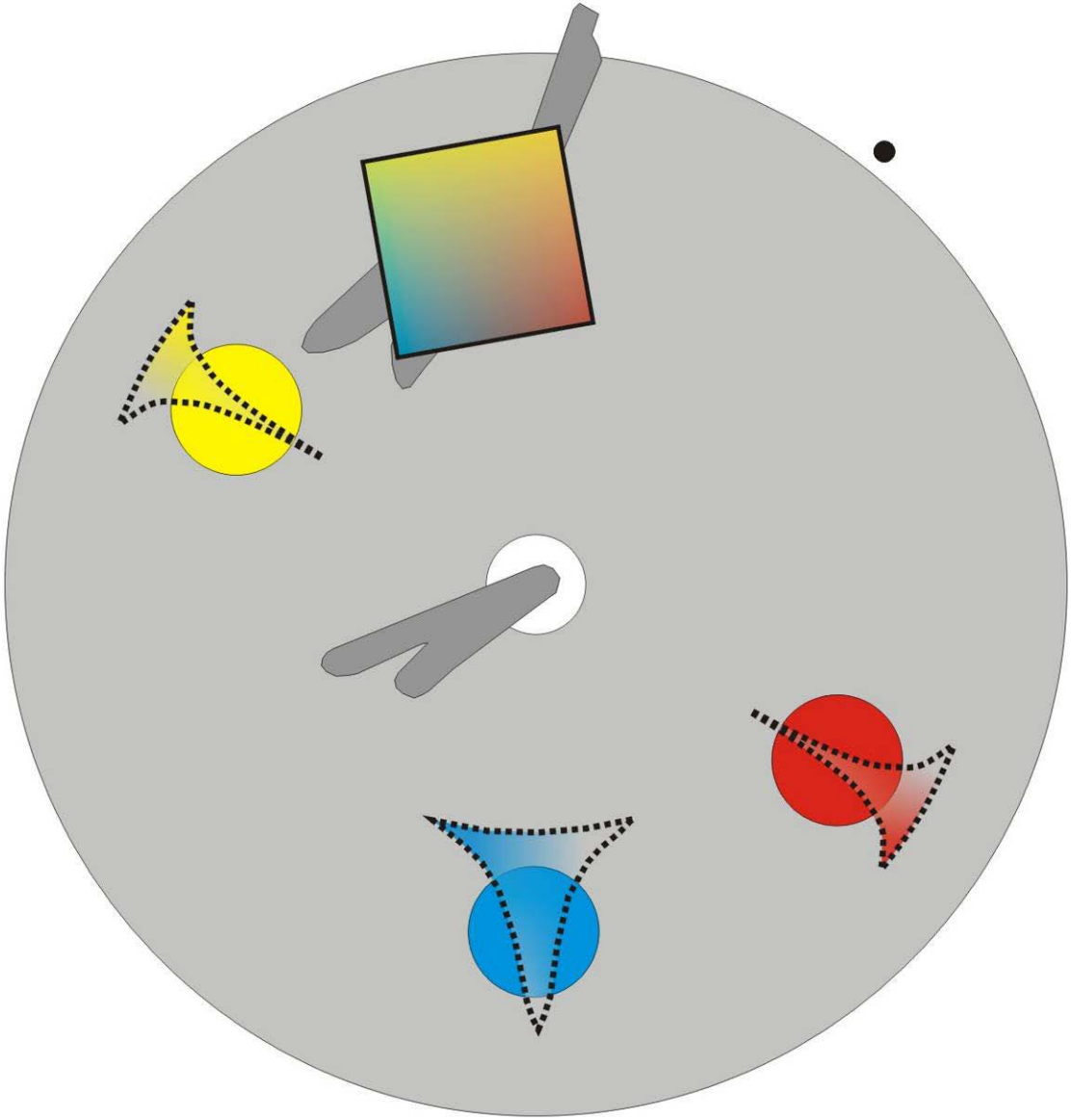


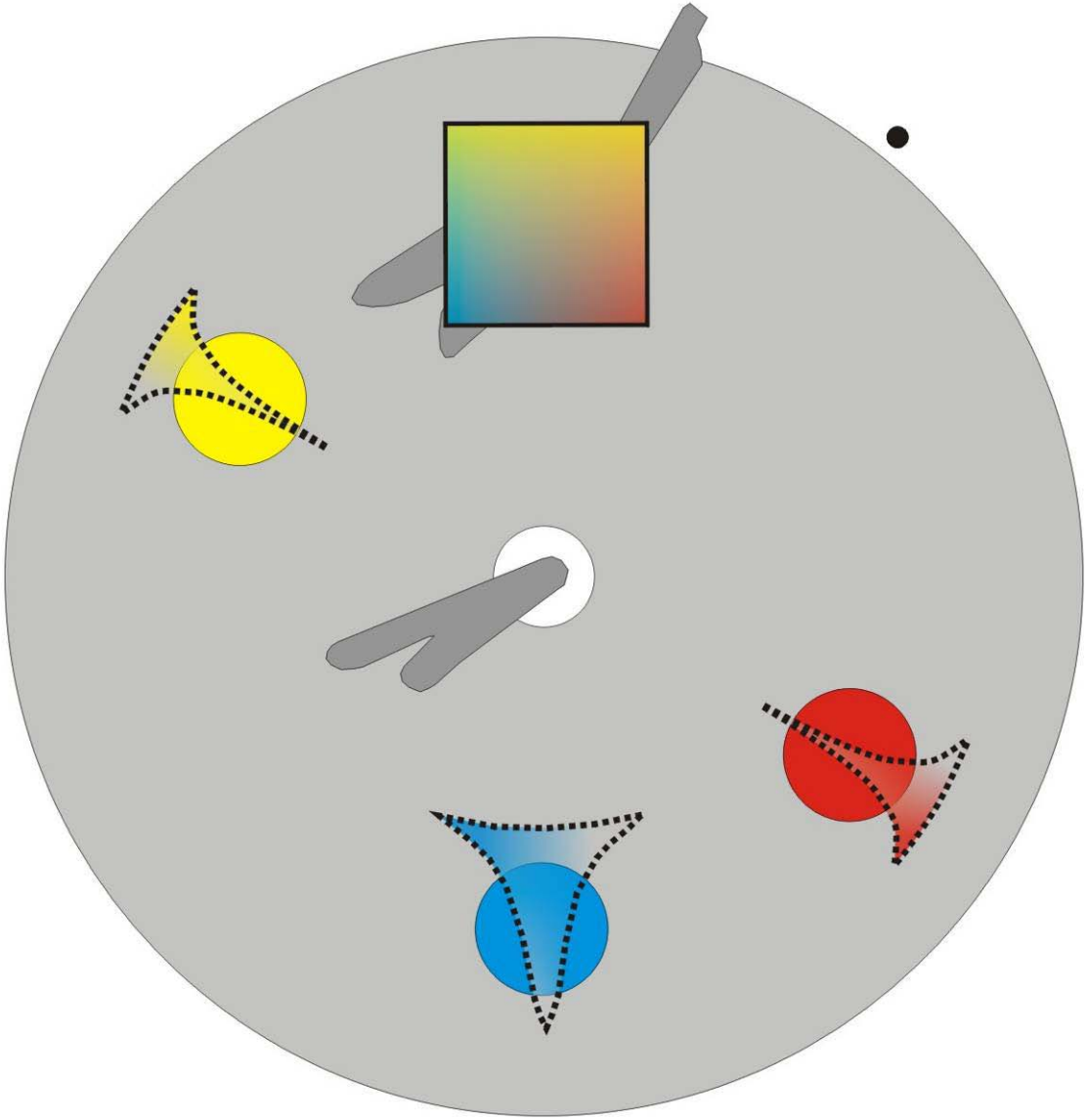


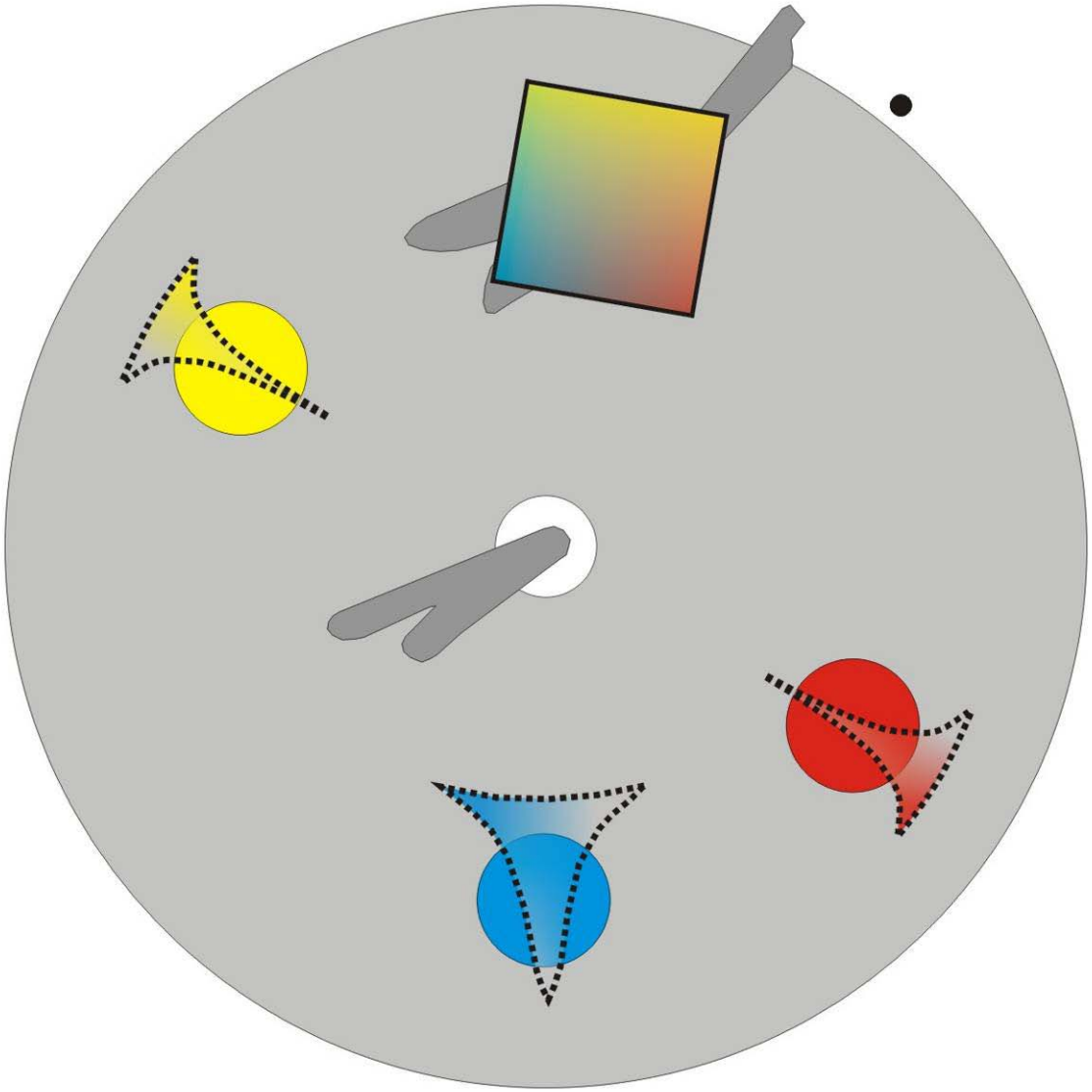


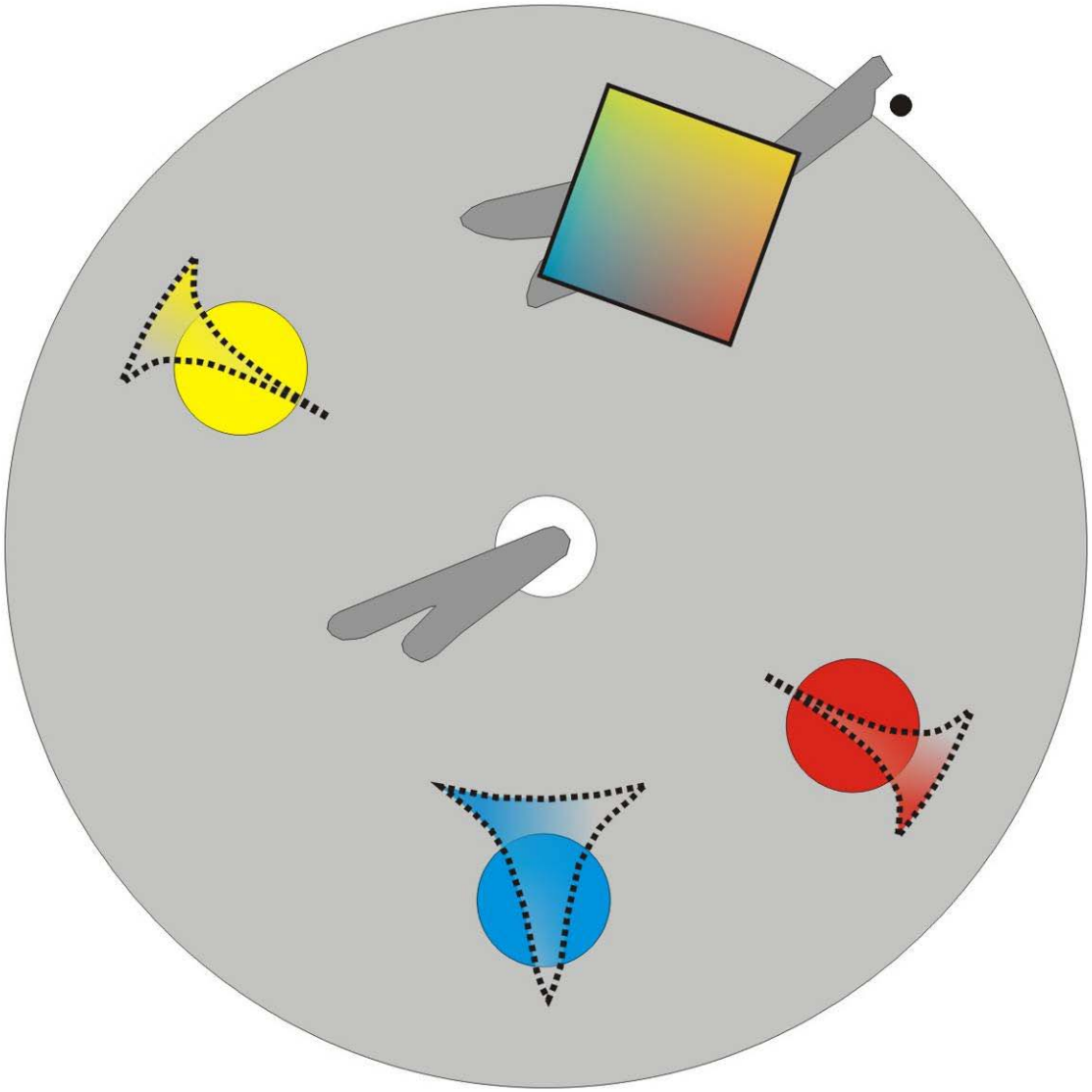


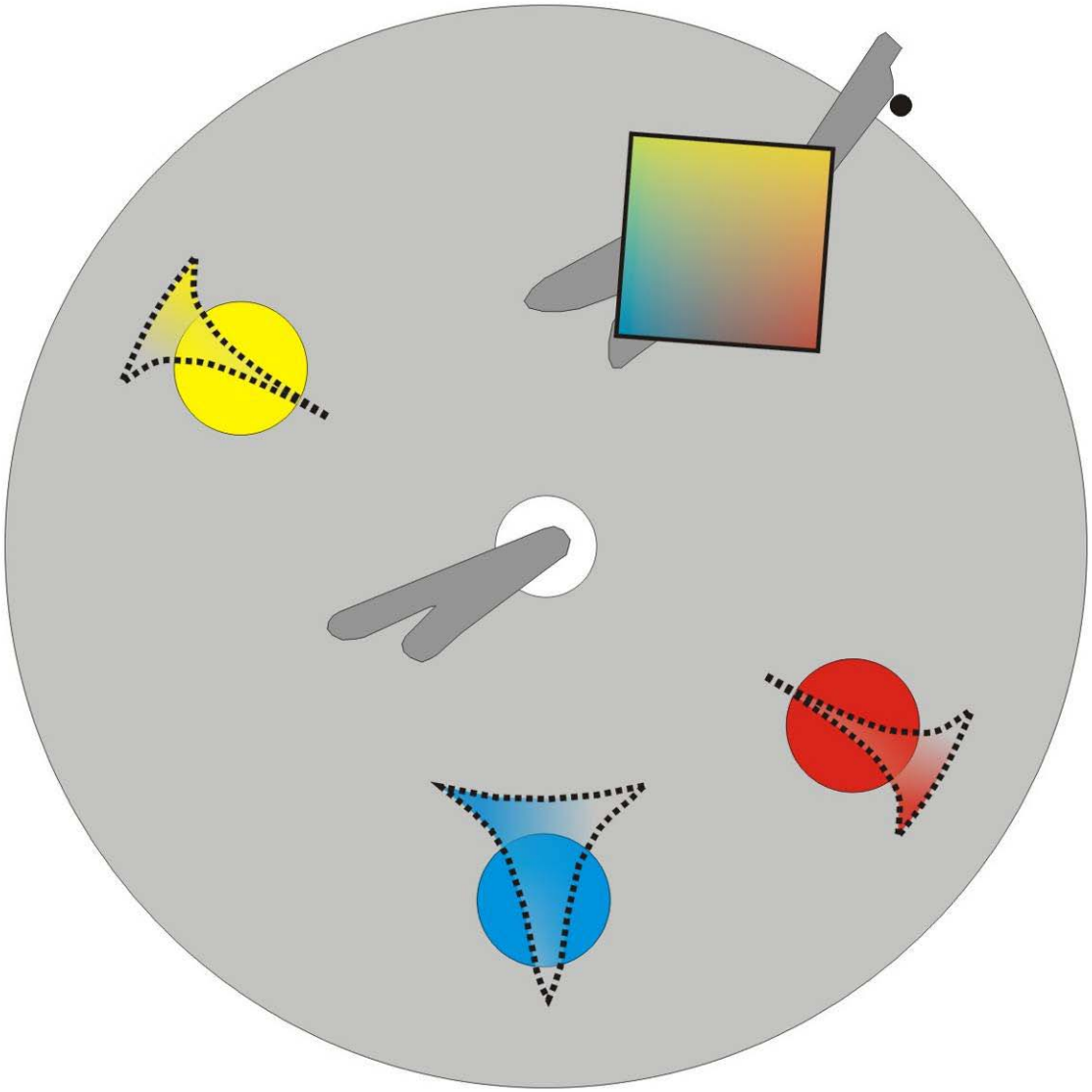


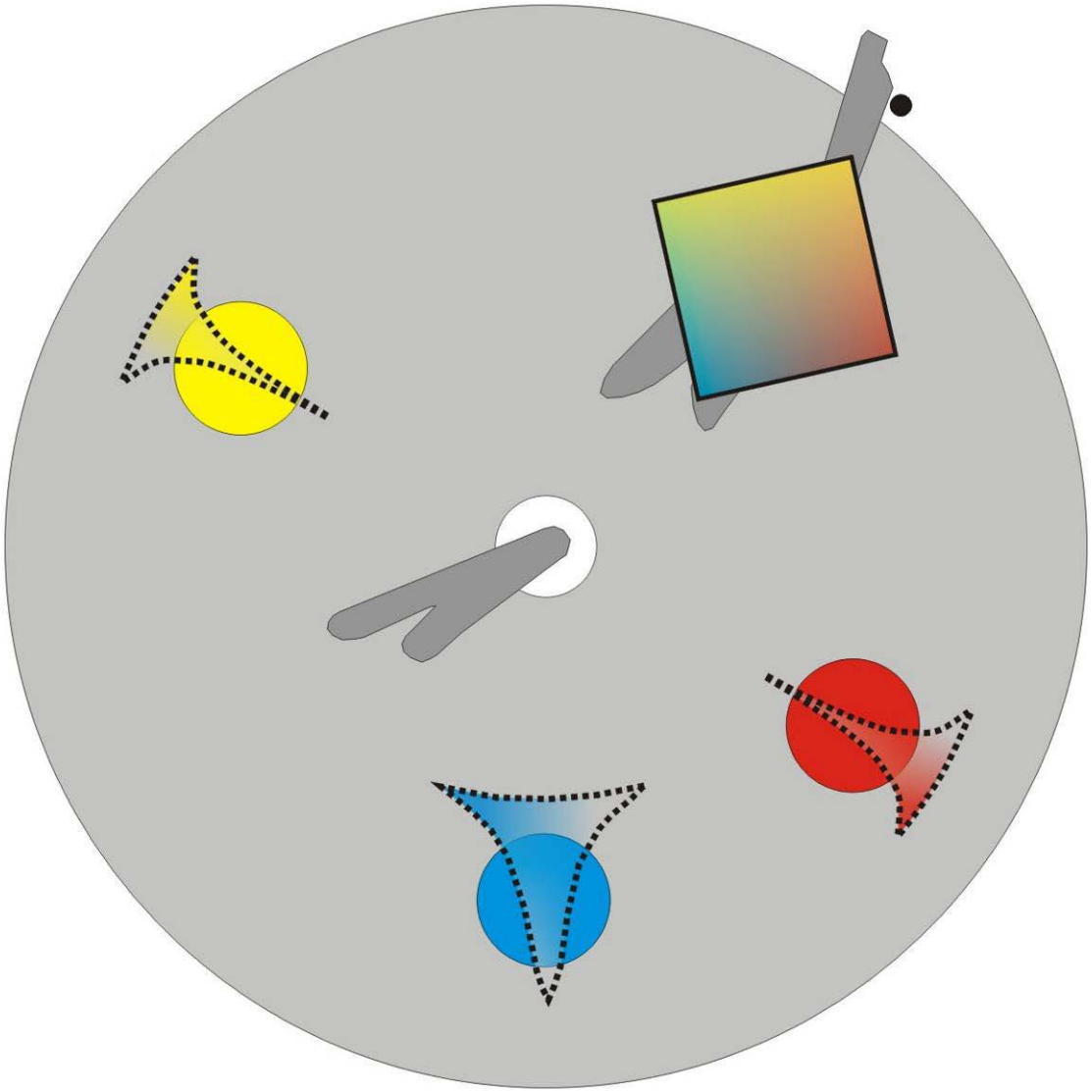


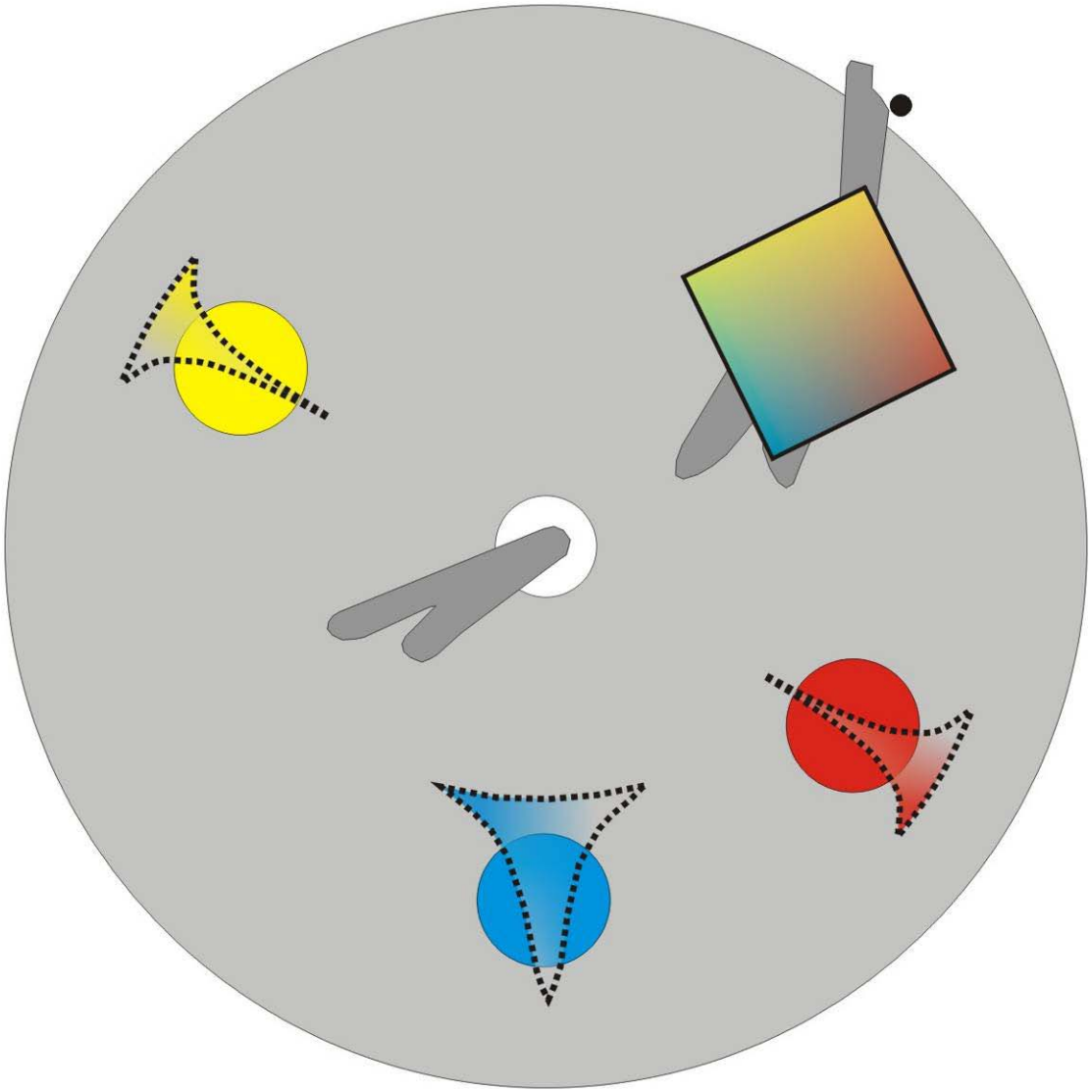


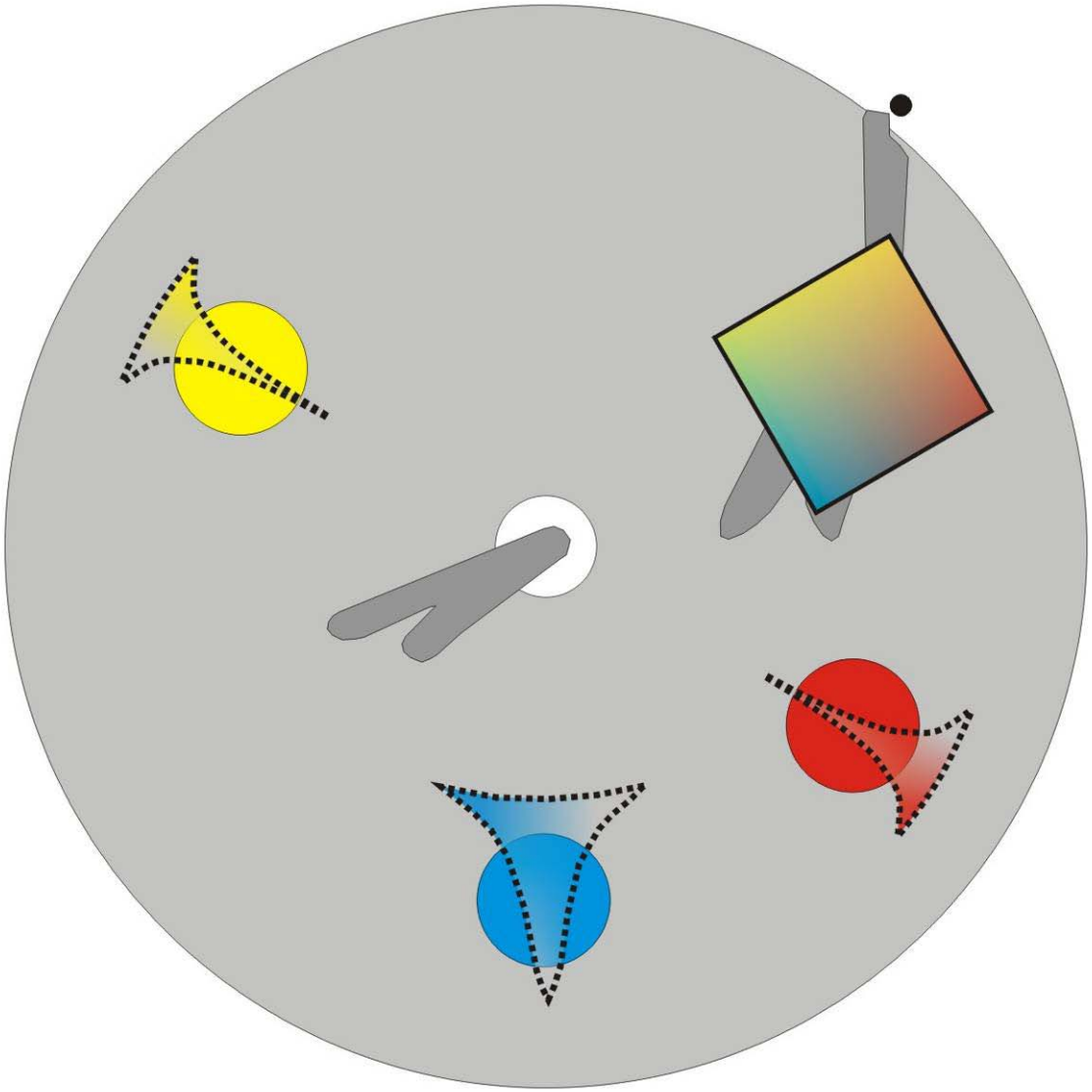


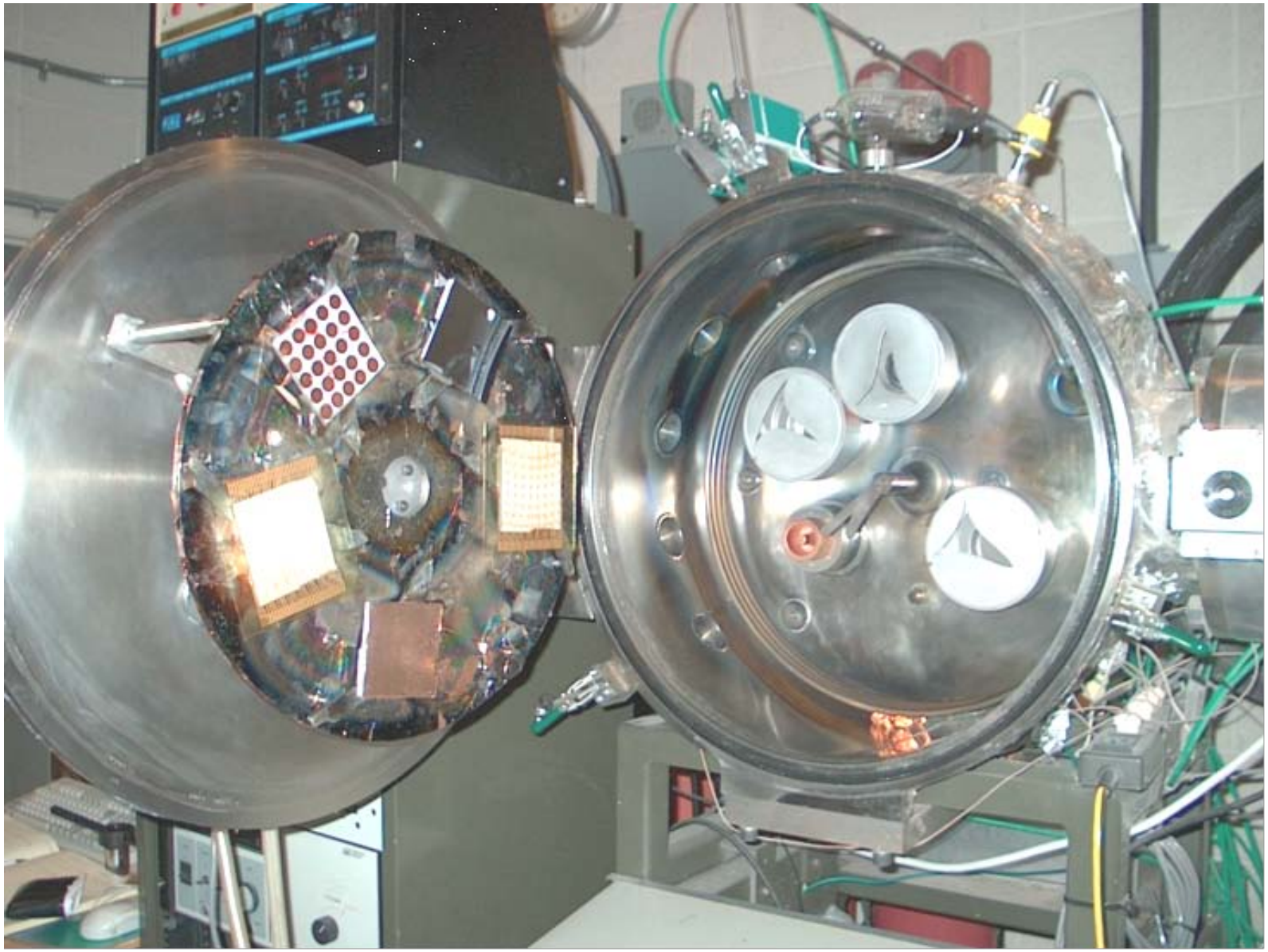


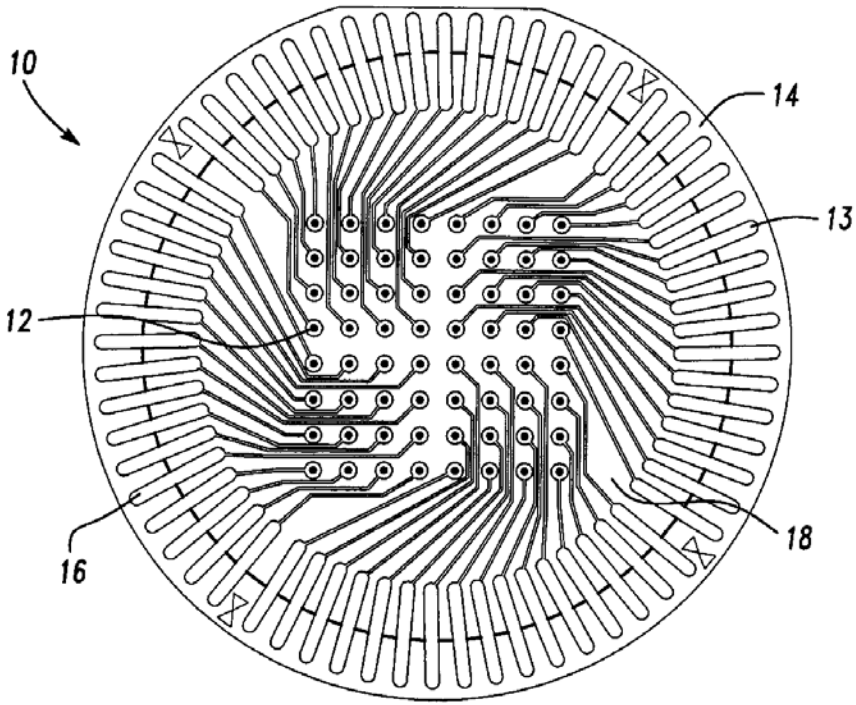




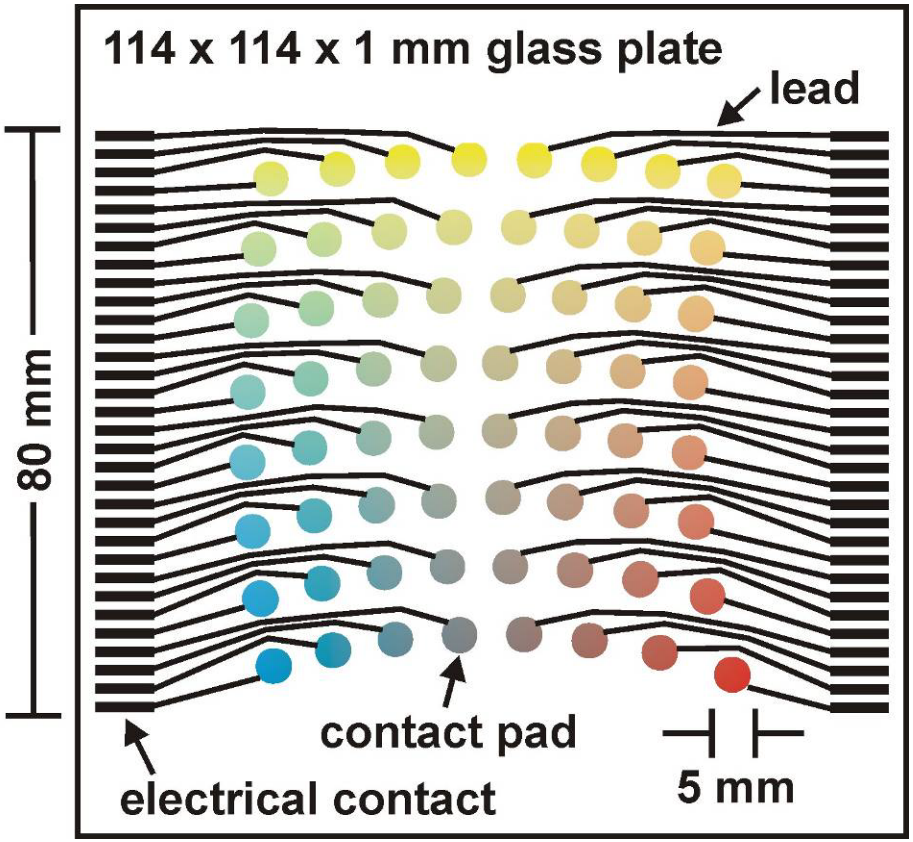




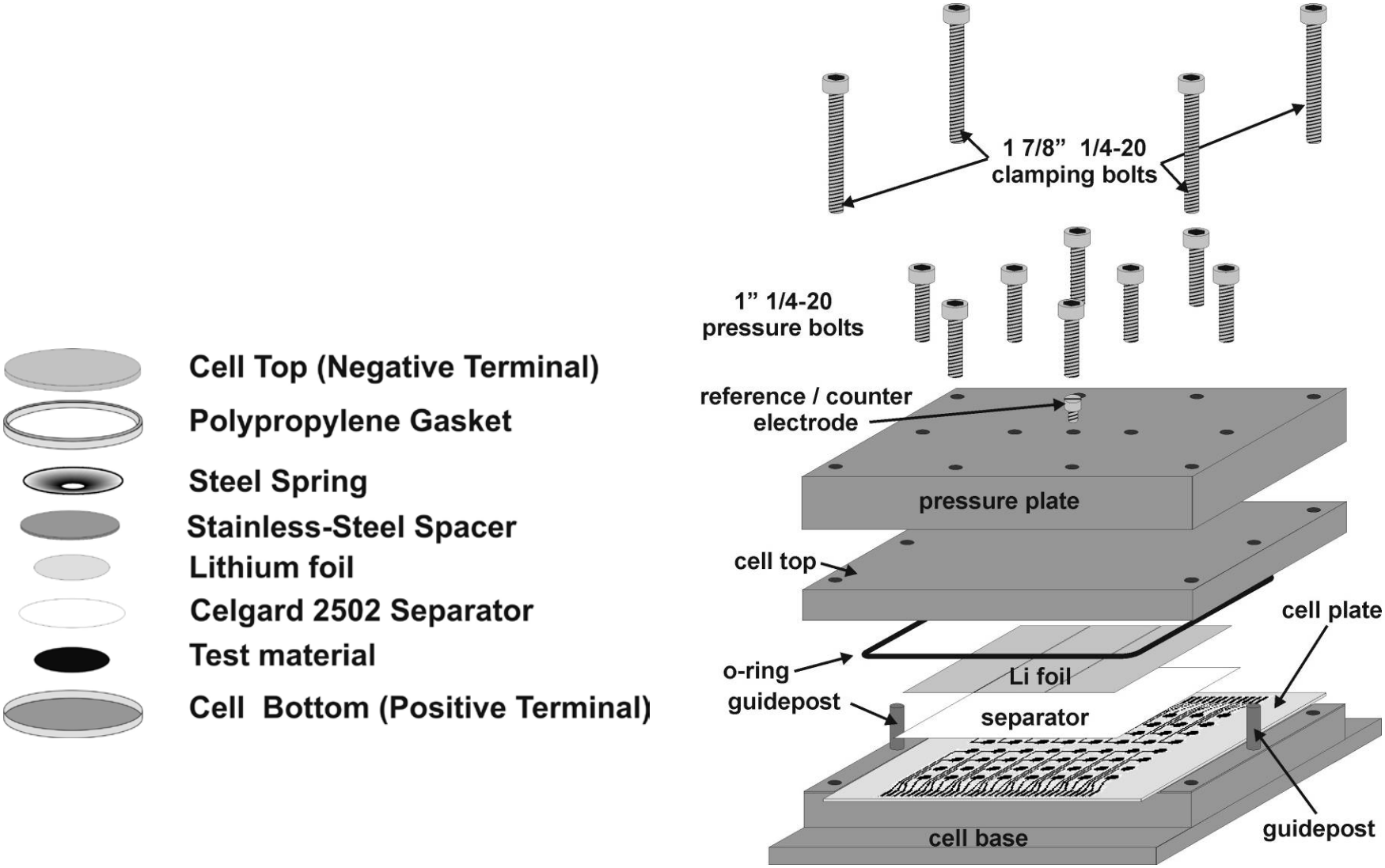




Warren *et al.*, US Patent 6,187,164.



Fleischauer *et al.* Meas. Sci. & Tech. **16**, 212 (2005).



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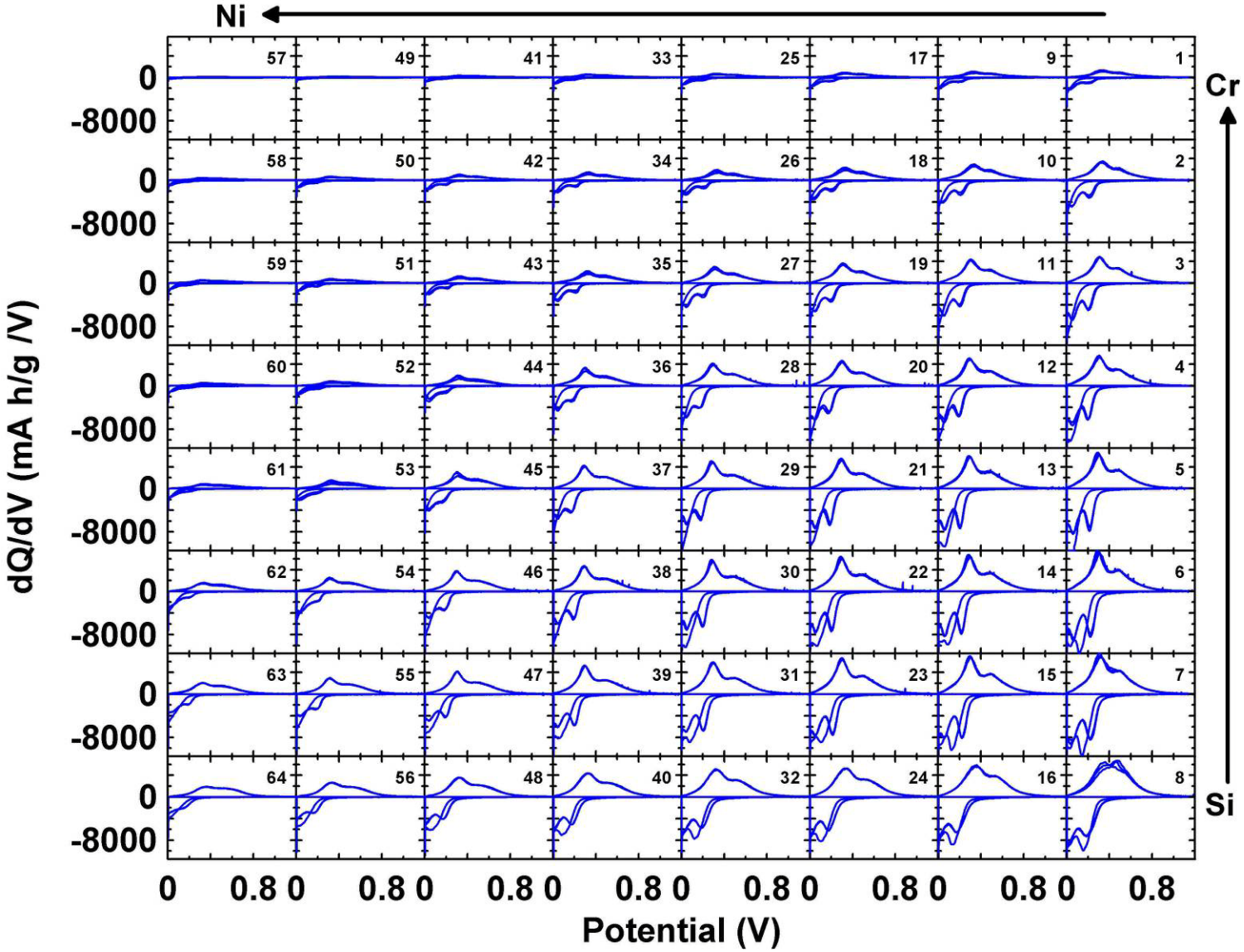
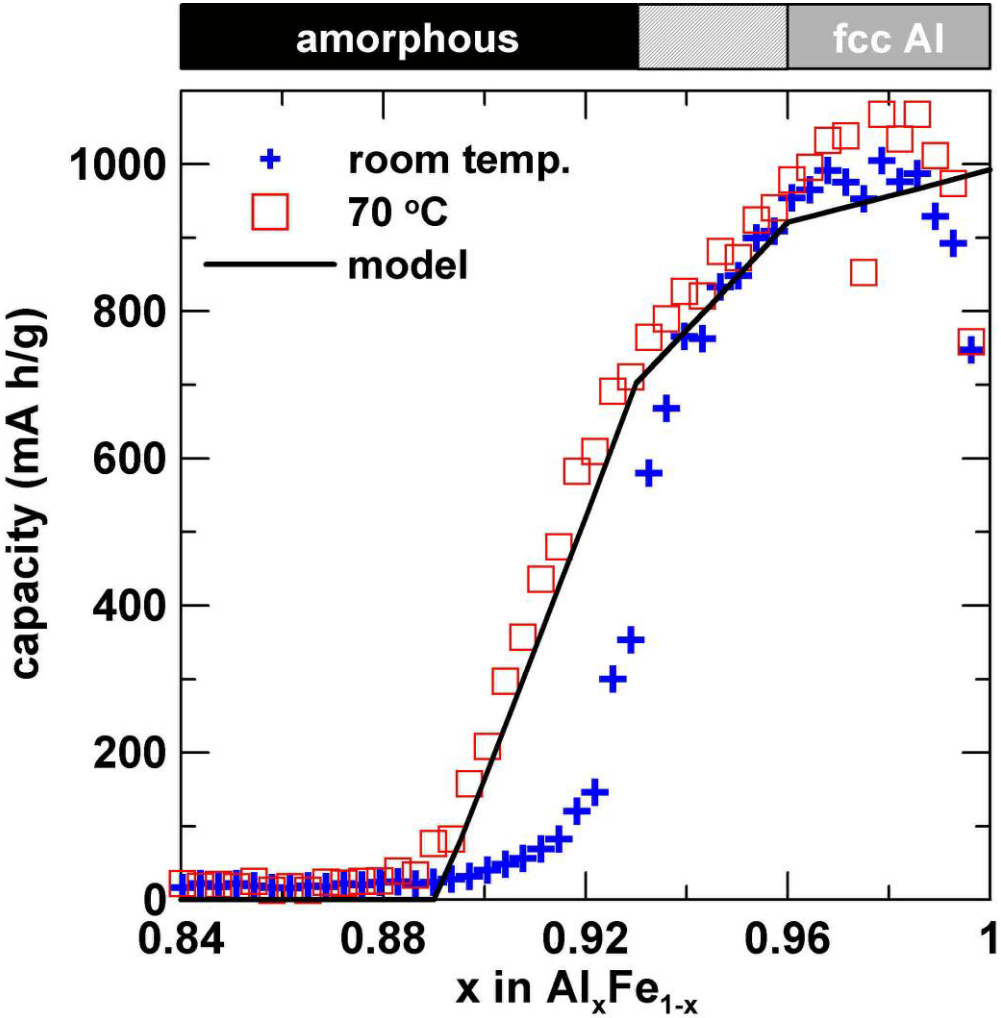


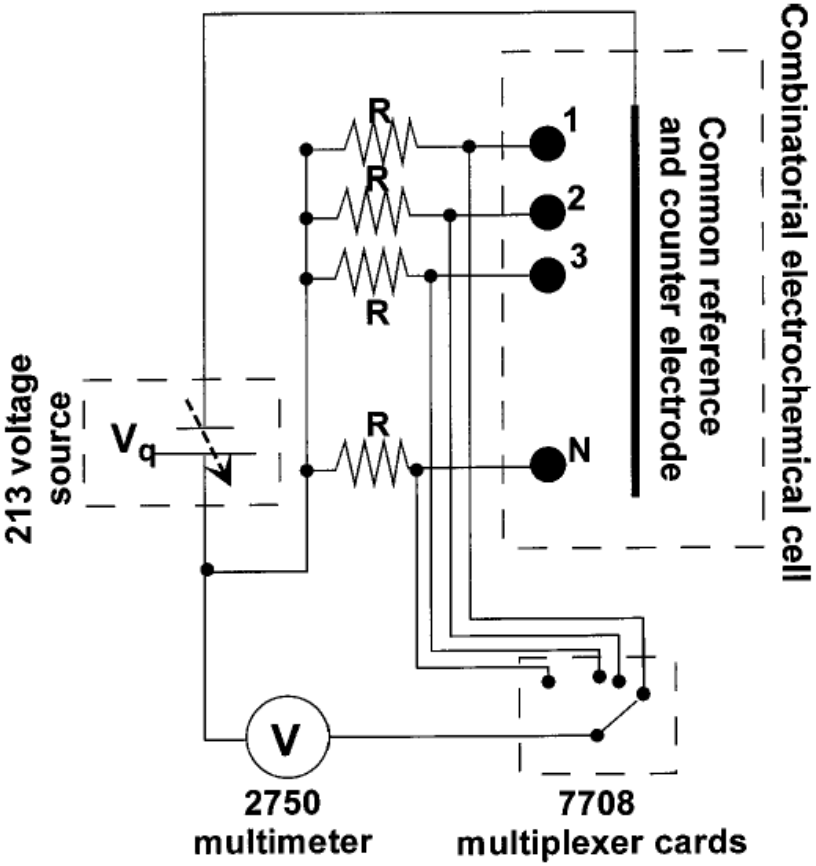
(see Fleischauer *et al.*, J. Electrochem. Soc., **154**, A151 (2007) for details.)



Fleischauer *et al.*, J. Electrochem. Soc., **153**, A484 (2006).

Cycling hardware and software

- Constant current is preferred, could lead to "cross talk"
- Interface with Keithley hardware
- In-house data collection, processing, display software



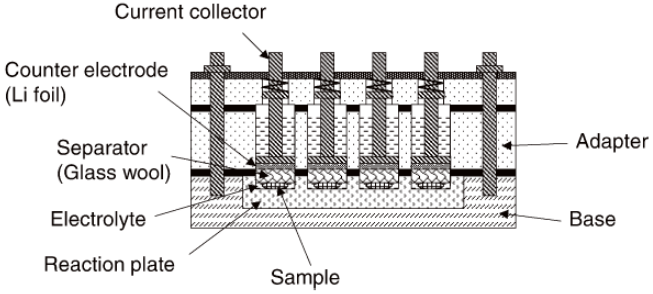
Cumyn *et al.*, Elec. Solid-State Lett., **6**, E15 (2003).

Hydrogen storage

- adaptable to NiMH batteries using $Ni(OH)_2$ in place of Li, KOH electrolyte
- Cost-effective (~$500 / cell, $20 / plate), multiple identical samples
- Temperature range limited by electrolyte
- Open / flooded cell also possible

Variable pressure cells?

- Existing cell design prone to leaks through (broken) glass plates, o-ring over leads
- Through-plate electrodes challenging to seal / re-use
- Single compartment cells only allow for single pressure for all channels
- Watanabe cell expensive (machined Pt)



Summary

- Combi methods can be very productive for battery work, not widely used
  - Predominantly thin films, liquid electrolyte
- Electrochemical cycling instrumentation relatively simple, cost-effective
- Extension outside of “basic” MH batteries is not trivial