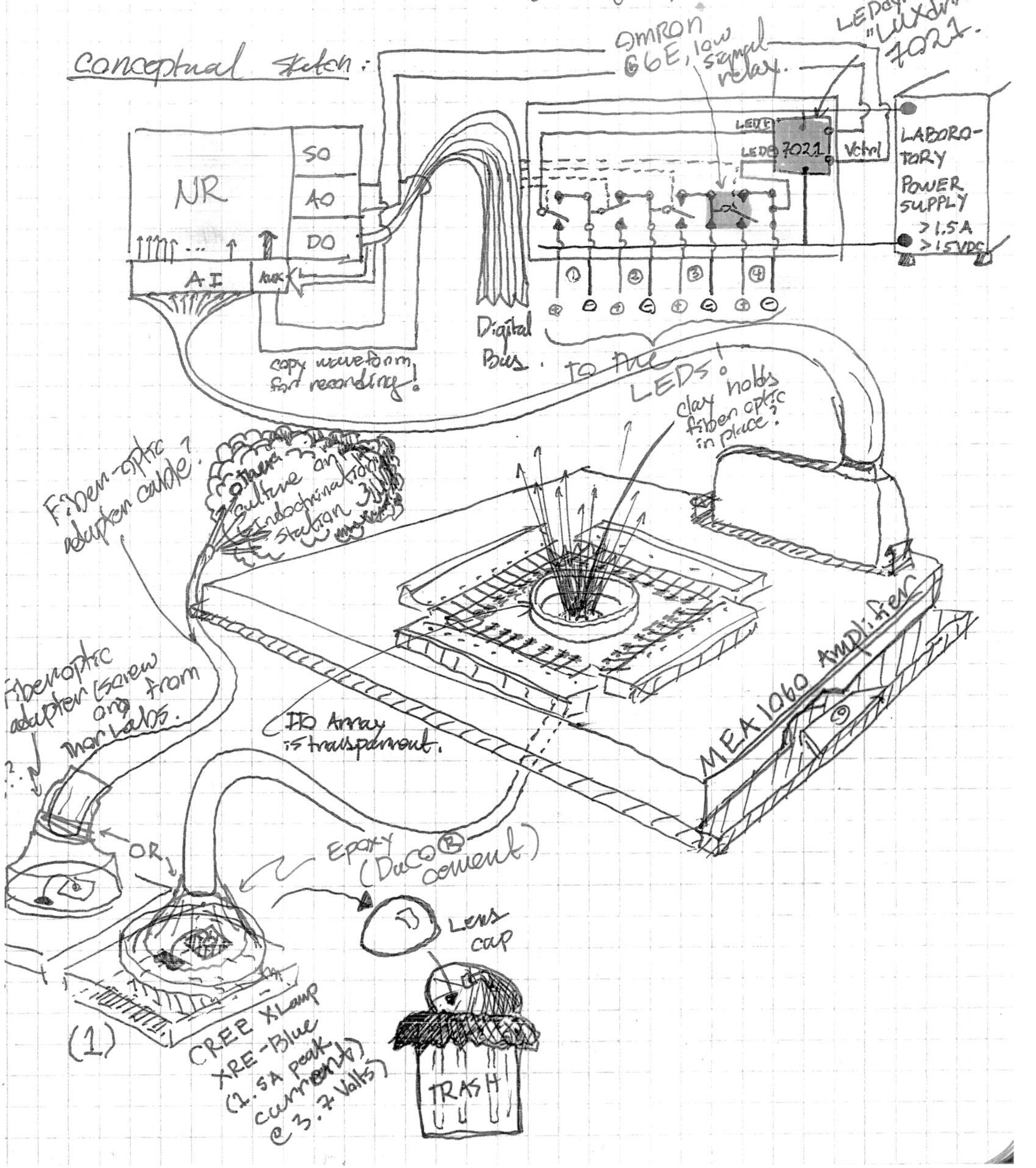
A ~~concept~~ for wide-field, ~~fast~~ LED-based optical stimulation - 3/24/2011

Purpose: come up w/ a low-cost, LED + Fiber optic based method for getting light to cells.

Conceptual sketch:



• Isaac. (3/25/2011), Phone conversation

> fiber optics → 200 um
> numerical apperature → small numerical appeature
smaller mode.
> multi-mode fiber.
> Isaac says direct LED coupling can be a bit finiky, requires machining some parts
↳ sending me a sample!

• Technical considerations.

1. Power supply

- Voltage of supply must be greater that all the forward Voltages of the LEDs, combined, at their peaker current.
- e.g. 4 CREE XLamps @ 1.5 Amps ⇒ Forward Voltage ≅ 4 Volts.

$\therefore V_{ps} \geq 16$ volts DC.

- The current output of PS must be greater than the peak current of a single LED, ~1.5 Amps.

2. SPDT switch for controlling multiple LEDs

- must support load current > peak current of single LED
- must be switchable w/ 5V TTL signal.

3. Fiber optic

- generally 200 um core, but we may want wider to get whole array.

- light speads from tip in a fashion based on the numerical apperature of the fiber.

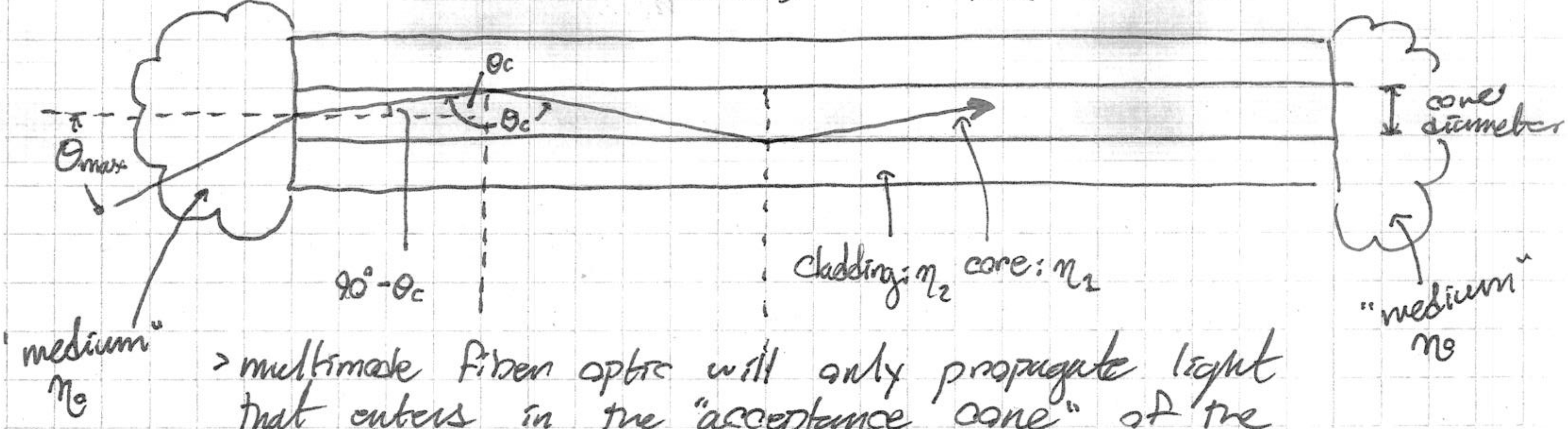
- numerical apperature

>(Campagnola, 2008) used 0.22 numerical apperature.

NA = sine(θ_{max}) where θ_{max} is the maximal ∠ allowing propogation down the optical fiber.

∴

$NA = 0.22 = \sin(\theta_{max}) \Rightarrow \theta_{max} = 12.709°$



> multimode fiber optic will only propagate light that enters in the "acceptance cone" of the fiber

> For a step-index multimode fiber, the acceptance ∠ is determined only by the indices of refraction of the core and cladding, η_1 and η_2 respectively.

$$\eta_0 \sin\theta_{max} = \sqrt{\eta_1^2 - \eta_2^2}$$

> above, θ_c is the critical angle for <u>total internal reflection</u>

$$\theta_c = \sin^{-1}\left(\frac{\eta_2}{\eta_1}\right)$$

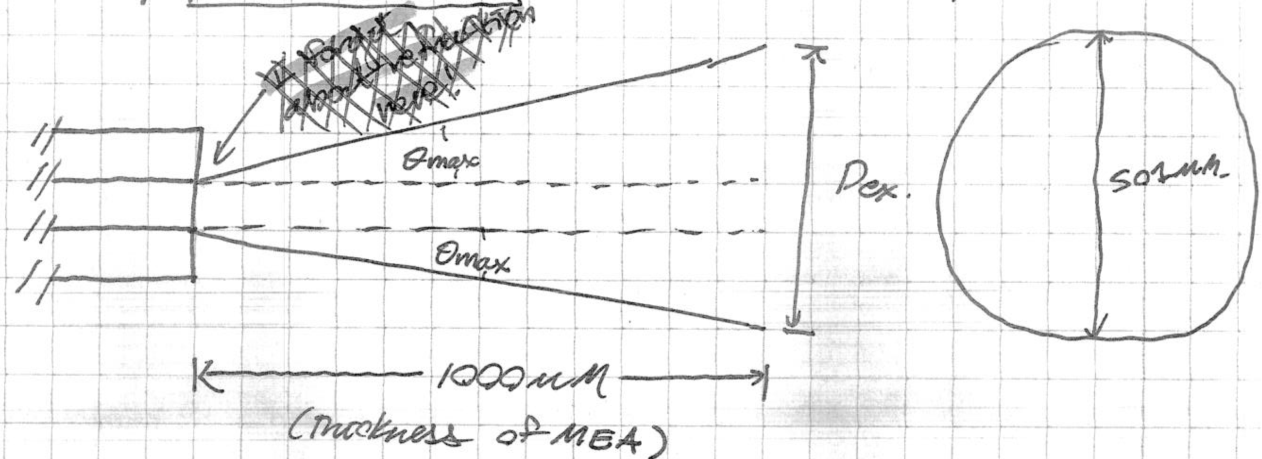
> snell's law

$$\eta_0 \sin\theta_{max} = \eta_1 \sin\theta_r = \eta_1 \sin(90° - \theta_c) = \eta_1 \cos\theta_c$$

$$\frac{\eta_0^2}{\eta_1^2}\sin^2\theta_{max} = \cos^2\theta_c = 1 - \sin^2\theta_c = 1 - \frac{\eta_2^2}{\eta_1^2}$$

$$\therefore \ \eta_0 \sin\theta_{max} = \sqrt{\eta_1^2 - \eta_2^2} \qquad \eta_{air} \cong 1.0$$

> so w/ $\boxed{\theta_{max} = 12.709°}$ and 50 uM core,



$D_{ex} = [1000 \cdot \tan \theta_{max} + 25] \cdot 2$

$D_{ex} = 501$ uM. (matches figure 4 of paper nicely).

> with a 200 uM core,

$D_{ex} \cong 650$ uM.

> ~~when~~ using direct coupling (lens of LED removed) (Campagnola, 2008) report 32 mW/mm² at the fiber optic tip, but falls ~~exponentially~~ parabolically as a function of distance.

32 mW/mm² @ tip w/ area $0.1m^2 \cdot pi = 0.0314\ mm^2$.

to

x mW/mm² @ culture w/ area $0.65^2 pi = 1.327\ mm^2$.

x mW/mm² = 0.75 mW/mm², which is not powerful enough to excite the cells.

> I think I need to better understand how to efficiently couple the Fiber optic to the LED

> may want to use f.o. w/ a larger core → size of the array is 800 uM × 800 uM. → get f.o. w/ 1mm core or larger.

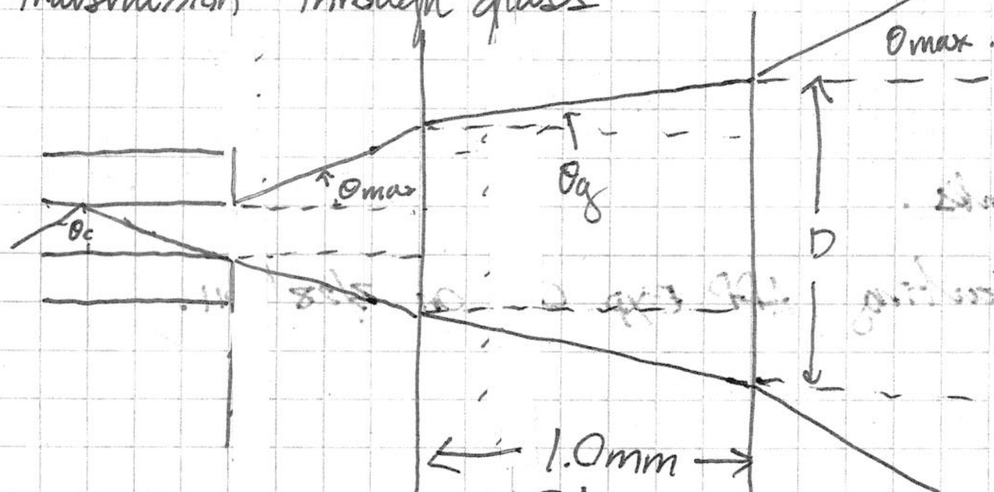
Summary of my findings

- Not too much out there to couple H.P. LED's to Fiber optics. Tons of stuff to couple laser diodes to them, but they are ~$4,000 for 473nM and require a special driver.

- For culture-wide excitation [modulation] we can use large diameter multi-mode fiber-optics butt-coupled directly to high power LEDs. These can be glued in place w/ epoxy.

- I found really cheap lenses specifically for CREE XR-E LED's!
  - ↳ probably not necessary though.

- transmission through glass



MEA glass.
($n \cong 1.5$)

$$\theta_g = \frac{\sin(\theta_{max}) \cdot n_{air}}{n_g} = \frac{\sin(\theta_{max}) \cdot 1.0}{1.5}$$

$$= 0.66 \sin(\theta_{max})$$

∴

$$D \cong D_{core} + \tan(\theta_g) \cdot 1mm = D_{core} + \tan\left[0.66 \sin(\theta_{max})\right]$$

[continued on pg. 11]

and since the Numerical Apperature (NA) is

$$NA = \sin(\theta_{max}) \Rightarrow \theta_{max} = \sin^{-1}(NA).$$

$\therefore$

$$D_{blue} = D_{core} + \tan(0.66 \cdot NA) \cdot 1mm.$$

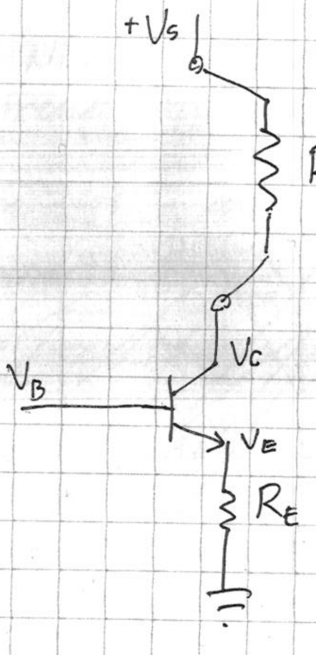
So, here are some values for different fibers:

NA	Core Diameter	D blue
0.22	50 uM	196 uM
	200 uM	~~200 uM~~ 346 uM
	1000 uM	1.146 uM
0.37	50 uM	299 uM
	200 uM	449 uM
	1000 uM	1249 uM.
0.48	50 uM	378 uM
	200 uM	528 uM
	1000 uM	1328 uM.

So we see that the NA is almost neglegable and the most important thing is core diameter.

• Matches NR's capabilities just fine.

• Making a current source w/ a transistor



> Basic transistor idea

$$I_C = h_{FE} I_B = \beta I_B$$

$\beta \cong 100$ (current gain)

> collector voltage is more positive than emitter voltage.

1. ~~Emmit~~ Emitter-follower relationship

$$V_E = V_B - V_{FD} \qquad V_{FD} \cong 0.6 \text{ volts.}$$

2. Ohm's law.

$$I_E = \frac{V_E}{R_E} = \frac{(V_B - 0.6)}{R_E}$$

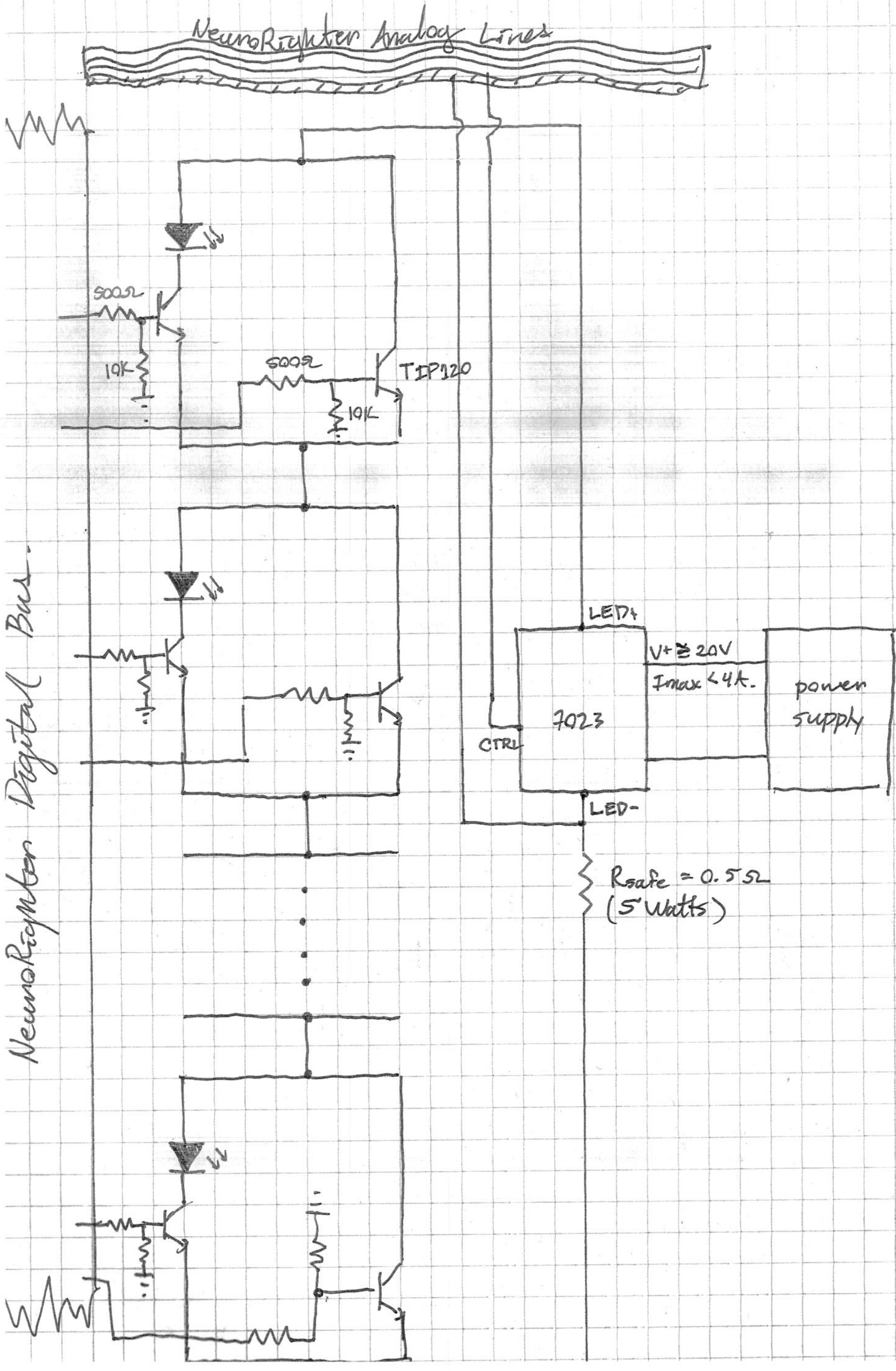
3. $I_E \cong I_C$ for large β and ∴

$$I_C \cong (V_B - 0.6 \text{ volts}) / R_E$$

so the current can be controlled by varying R_E, or by varying V_B (like I am doing).

• The problem: Need fast switches that can support a lot of current > 1.5 A.

↳ what about a transistor switch?


NeuroRighter Analog Lines
NeuroRighter Digital Bus.
500Ω
10K
500Ω
TIP120
10K
LED+
V+ ≧ 20V
Imax < 4A.
7023
CTRL
power supply
LED-
Rsafe = 0.5Ω
(5 Watts)

· So I think these are workable options, but they will require circuit testing to see advantages + Disadvantages.

· To test these circuits, I went to order the following parts:

1. LED + accessories

a. CREE Xlamp XR-E, blue DK# XREBLU-L1-R250-00K01C
b. CREE Xlamp XP-E, blue DK# XPEBLU-L1-0000-00201CT-N
c. Ledil LC1-RS X-lamp lens DK# 711-1139-ND
d. optical Grade Epoxy
Dymax OP-4-20632
Thorlabs, glass to plastic Bond TL# NOA68
glass to glass NOA63

2. Power supply stuff.

a. 0.5 Ω, 5 watt Resistor
[high current] b. 20A, 13.8 VDC power supply DK# TL272-ND
~~c. fan~~

3. Constant-current LED Driver

a. 0.5 Ω, 5 watt Resistor
b. LEDdynamics LUXdrive CC IC DK# 788-1007-ND
c. RECOM LED Driver (CC) DK# 945-1128-ND
d. Darlington-pair integrated cir. DK# TIP120-ND

4. Misc

12VDC a. Fan for anhillatrix (120mm²) 150mm screw spacing x 20mm Deep DK#
b. Perf-boards for prototyping 1 DK# 8016-7
c. perf-boards for prototyping 2 DK# V2025-ND
d. " " " DK# V1027-ND