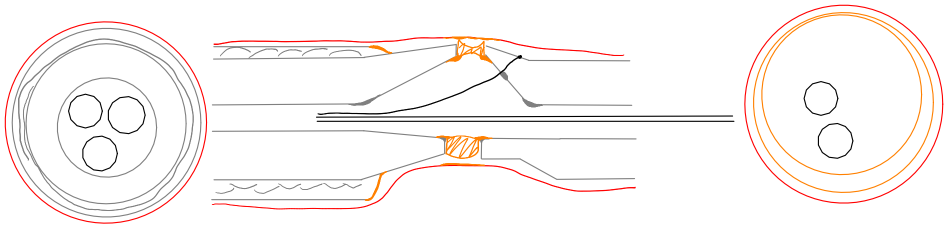
Single direction controlled bend cable.

Polish is to be run through bowden channel until smooth then washed by <0.35um ultrapure liquid.

Biocompatible grease (not oil) is to fill channel.

Eccentric elastic spacers are sliced rubber. Wires are carbon fiber. All other parts - tubing, helical winding, pressure sensor - are counter-wound flat strips.



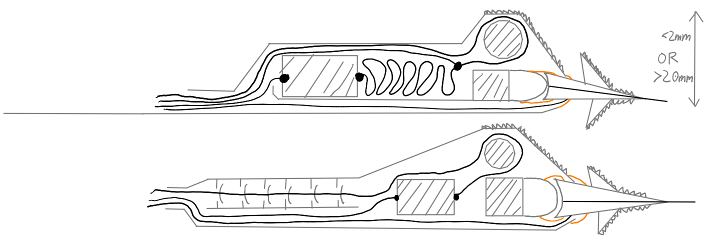
Channel diameter may be kept larger than desired wires by adding removable wires during assembly (which are pulled out later). Or if available (>>250um), heat-shrink teflon tubing may be usable.

Always consider including extra wires for addition of subsequent 'stages' later.

Simple 1D pressure sensor allows iterative software controlled mechanical compliance.

Two directional impact moles. If entire cable cannot be rotated due to insufficient compensating joints, multiple tip puller cables may be required. Needle tip may be multi-walled carbon nanotube.

Machining from a flat plate of metal is sufficient except for tip, ball/socket joint, and hammer.

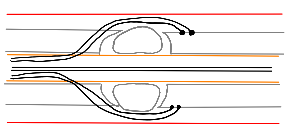


Slow motions from less than ideal bowden cables or slow actuators may be converted to rapid impact events by any means of mechanical or inertial energy storage.

A less than ideal bowden cable may be given some 'slack' that will be taken up before impact, allowing friction to pull the cable taunt before impact.

Slow actuator may use metal bending to store energy along an arbitrary length of bowden cable, generating strong impact.

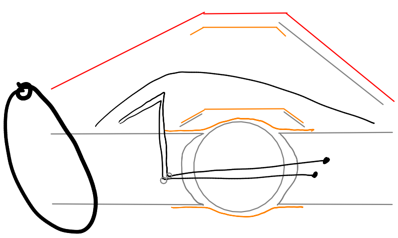
Elastic connections shown are not expected to experience any substantial adverse forces. Spherical ball/socket joint must be self-centering under forward pressure.



Ball and socket joint with internal constant-length core. Bending radius limited by crush of pass-through cables.

May be used without any external control, to allow a freely bendable joint of constant length. A cable consisting of such joints at regular intervals may zigzag parallel to or twist around another set of joints.

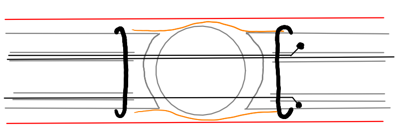
Multiaxis surface machining, or additive manufacturing, may be required for external channels (simple drilling but at an angle).



Constant length cable twisted around and tied to bendable core. Relies on sliding motion between cable and core to maintain constant length of both.

May allow tighter bending radius.

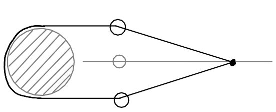
Specialized rings may be required to hold fibers inside surface machined notches.



Cables tied (or held by rings) within notches. May allow tight bending radius and low cost.

Lack of constant-length channels may necessitate additional travel and compensation for subsequent 'stages' .

Crossing between channels may limit or control twist. Two pairs of crossed wires are expected to allow full three-axis control.



Ball-and-socket joint may be controlled by a pair of motors or another ball-and-socket joint.

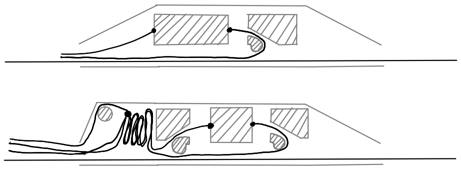
Four wires instead of three - adding an 'unnecessary' wire may in some cases allow linear trading of motion between pairs of wires, allowing bidirectional control from a single rotary axis. In turn, this may also allow inexpensive gearboxes to be added efficiently.

However, any deformation - elastic or otherwise - will at best introduce backlash. Separate force driven cable pullers are usually preferable both due to this and the possible mechanical improvement in stiffness from more optimal use of fewer wires without internal elasticity.

Crossing wires also may be possible (ie. with some ball joints), adding twist control as well (which may or may not be desirable).

Inline impact mole. May add impact force to actuated cables, or may be placed prior to a highly directional tip.

Simple surface machining will suffice. Anvil impact transfer may improve slightly if wedge is driven into cable gap (discouraged).

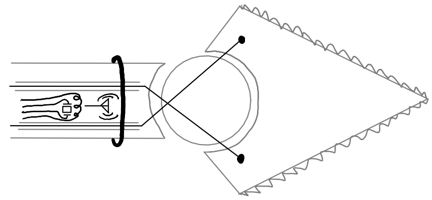


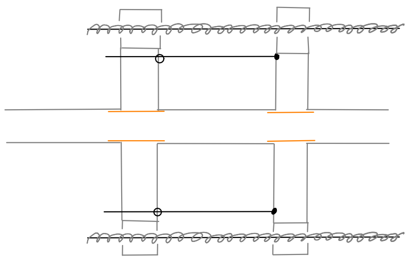
High angle tip. May be placed after inline impact mole, with or without any other joints.

May also be used as a needle tip to push threads.

Tip may be smaller, less abrasive, and may omit multiwalled-carbon-nanotube, if only soft material is expected.

Tip may be blunt if only soft tunnel is expected.

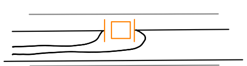




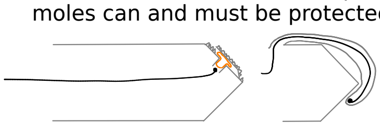
'Conventional' 'tentacle' bowden cable topology as reported by 'HackADay' article.

Small bowden actuators may be much more useful with some knowledge of the local environment. Specifically, it may be highly desirable to know whether nearby structures must be preserved (ie. capillaries) or whether a tissue boundary has been reached.

Piezoelectric crystals may translate mechanical, resistance, and pressure from bowden cable actuators, deriving tactile feedback from force and texture interactions.

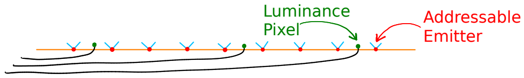


Sensors at the surfaces of impact moles can and must be protected.



Switching emitters is expected to allow differential determination of transmittance and reflectance at each emitter, even if luminance pixels are substantially less frequent.

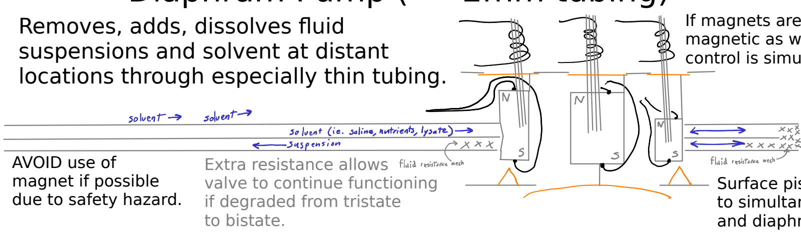
Bidirectional use of luminance pixels is expected, allowing the switchable emitters to be omitted. A pure fiber optic implementation with at least as many pixels as fibers is feasible. Multiplexing may be unnecessary as the total number of pixels is expected small for usual applications.



Diaphram Pump (<<2mm tubing)

Removes, adds, dissolves fluid suspensions and solvent at distant locations through especially thin tubing.

If magnets are used, external magnetic as well as bowden control is simultaneously possible.



AVOID use of magnet if possible due to safety hazard.

Extra resistance allows valve to continue functioning if degraded from tristate to bistate.

Surface pistons are also able to simultaneously push valves and diaphram